SPAWNING ESCAPEMENT GOAL REVIEW OF BRISTOL BAY SALMON STOCKS

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ABSTRACT

The Alaska Department of Fish and Game held numerous meetings to review Pacific salmon *Oncorhynchus* escapement goals for the major river systems in Bristol Bay. Spawner-return data for sockeye salmon *O. nerka* were analyzed for the Alagnak, Egegik, Igushik, Kulukak, Kvichak, Naknek, Nushagak, Togiak, Ugashik, and Wood Rivers. Additionally, we evaluated spawner-return data for Alagnak, Egegik, Naknek, Nushagak, and Togiak River chinook salmon *O. tshawytscha*; Nushagak River chum salmon *O. keta*; Kulukak, Nushagak, and Togiak River coho salmon *O. kisutch*; and Nushagak River pink salmon *O. gorbuscha*. In many instances, the available data supported a change to the current escapement goals in Bristol Bay.

The upper range of Kvichak River pre-peak/peak, Togiak, Ugashik, and Egegik River sockeye salmon goals were increased. Both ends of the range were increased for Igushik and Naknek River sockeye salmon. The committee recommended no change for the Kvichak River off-cycle, and the Nushagak and Wood River sockeye salmon escapement goals. The committee recommended an escapement goal range for the existing Nushagak River chinook salmon point goal. The committee recommended the creation of Kulukak River sockeye salmon, Nushagak River chum salmon, and Alagnak and Egegik River chinook salmon escapement goals. Kulukak River coho salmon and Nushagak River pink and coho salmon goals were evaluated but dropped because they are no longer assessed for escapement. The committee recommended changing the following four biological escapement goals to sustainable escapement goals: Alagnak River sockeye salmon, Togiak River coho salmon, and Naknek and Togiak River chinook salmon.

KEY WORDS: Pacific salmon, *Oncorhynchus,* sockeye salmon, *Oncorhynchus nerka*, chinook salmon, *Oncorhynchus tshawytscha*, chum salmon, *Oncorhynchus keta,* coho salmon, *Oncorhynchus kisutch,* pink salmon, *Oncorhynchus gorbuscha,* Bristol Bay, Kvichak River, Alagnak River, Naknek River, Egegik River, Ugashik River, Wood River, Igushik River, Nushagak River, Kulukak River, Togiak River, spawning escapement goal, Ricker stock-recruitment model, smolt.

INTRODUCTION

Bristol Bay, Alaska, supports some of the largest sockeye salmon *Oncorhynchus nerka* runs in the world. Combined sockeye salmon runs to Bristol Bay have averaged 36 million for the last 10 years with nine major river systems producing more than 99% of the returning sockeye salmon (Alagnak, Egegik, Igushik, Kvichak, Naknek, Nushagak, Togiak, Ugashik, and Wood Rivers; Table 1, Figure 1). Management of these sockeye salmon runs is based on achieving spawning escapements for each river within a specific escapement goal range. Individual biological escapement goals (BEG) have been used for the major river systems since the early 1960s. The Alaska Department of Fish and Game (ADF&G) reviews the BEGs for Bristol Bay rivers on a schedule that corresponds to the Alaska Board of Fisheries triennial cycle for considering area regulatory proposals.

This report documents a review of escapement goals for Bristol Bay salmon stocks. Escapement goals were reviewed based on the Policy for the Management of Sustainable Salmon Fisheries (SSFP; 5 AAC 39.222) and the Policy for Statewide Salmon Escapement Goals (EGP; 5 AAC 39.223). The Alaska Board of Fisheries adopted these policies into regulation during winter 2000-2001 to ensure that the state's salmon stocks are conserved, managed, and developed using the sustained yield principle. These new guidelines state that escapement goals be a range with a lower and upper value, rather than a single point estimate. Two important terms defined in the SSFP are:

biological escapement goal: the escapement that provides the greatest potential for maximum sustained yield (MSY); and

sustainable escapement goal (SEG): a level of escapement, indicated by an index or an escapement estimate, that is known to provide for sustained yield over a 5 to 10 year period, used in situations where a BEG cannot be estimated.

The escapement goal review committee (hereafter referred to as the committee) consisted of five Commercial Fisheries Division and three Sport Fish Division personnel (Table 2). The committee met numerous times and on 21-22 August presented results of their review to other department staff and additional participants from the United States Fish and Wildlife Service Office of Subsistence Management, National Park Service, and the Bristol Bay Science and Research Institute (Table 2).

The committee was formed to determine the appropriate goal type (BEG or SEG) and estimate the goal for each stock. All existing goals are BEGs and five of these did not have a range, only a point estimate. During the review process, the following escapement goals were evaluated:

- Chinook salmon *O. tshawytscha*: Alagnak, Egegik, Naknek, Nushagak, and Togiak River
- Chum salmon *O. keta*: Nushagak River
- Coho salmon *O. kisutch*: Kulukak, Nushagak, and Togiak River
- Pink salmon *O. gorbuscha*: Nushagak River
- Sockeye salmon: Alagnak, Egegik, Igushik, Kvichak, Naknek, Nushagak, Togiak, Ugashik, and Wood River, and Kulukak Bay

Formal committee meetings to discuss and develop recommendations were held on 6-7 March, 7 April, 17 April, 10 June, and 21-22 August. The committee also communicated by email. All

committee recommendations were reviewed by department regional and headquarters staff prior to being adopted by the department.

METHODS

Available escapement, harvest, and age data for each stock were compiled from research reports, management reports, and unpublished historical databases. The committee evaluated the type, quality, and quantity of data for each stock. This evaluation was used to determine the appropriate type of escapement goal as defined in regulation. If a sufficiently long time series of escapement, harvest, and age estimates were available, and the estimates were sufficiently accurate and precise, the data were considered sufficient to estimate MSY (as per rules and methods in Hilborn and Walters 1992, Chinook Technical Committee 1999, Quinn and Deriso 1999) and to develop a BEG (Table 3). If a sufficiently long time series of escapement estimates were available, but estimates of age and/or stock-specific harvest were not, an SEG was determined instead of a BEG.

Biological Escapement Goal Determination

The team identified nine salmon stocks from Bristol Bay with BEG-quality data: sockeye salmon from the Egegik, Igushik, Kvichak, Naknek, Nushagak, Togiak, Ugashik, and Wood Rivers; and chinook salmon from the Nushagak River. All nine stocks have good escapement, harvest, and age data, and in some cases limnological data. Escapement is sampled by beach seine and visually counted using towers at Egegik, Igushik, Kvichak, Naknek, Togiak, Ugashik, and Wood Rivers. Escapement is sampled by gillnet or beach seine and estimated using hydroacoustics (sonar) for Nushagak River salmon. Harvest estimation for each stock is determined by catch location and age composition. Stock contributions for multi-stock fisheries (Naknek-Kvichak and Nushagak Districts) are estimated using documented methods (West 2003). Age data have been collected from both the escapement and harvest for all of these stocks.

The committee assumed that sockeye salmon harvested in each district originated from rivers within the district. Estimates of interceptions of stocks outside their district of origin, based on differences in scale growth, have shown that this is not true; use of interception estimates obtained during 1983-1995 did not substantially change spawner-return relationships (Menard and Miller 1997). Although interception estimates have not been obtained since 1994, information such as age composition differences among district catches and escapements suggests that no great differences in interception rates have occurred.

The BEG range was estimated for: 1) escapements producing average yields that are 90-100% of MSY (S_{MSY}), and 2) the yield approach, explained below, which also estimates MSY with corresponding 90-100% range. Systems with a single datum having a large influence on spawner-return model results (i.e., large escapements that occurred in 1980) were often tested with and without this datum to measure its impact on the relationship. Inclusion of these data in setting escapement goals was evaluated on a system-by-system basis and was largely dependent on their

level of influence on the spawner-return model and the contrast in the escapement data.

Spawner-Return Data

Salmon spawner-return data were analyzed for all available brood years. Annual runs were the sum of escapements and harvests. Methods used to estimate total runs (harvest plus escapement) are described in Bernard (1983). Sport and subsistence harvests were only included in total return estimates for the Nushagak River, and are considered minor components for the other systems.

Spawner-return data were analyzed using a Ricker (1954) stock-recruitment model to estimate MSY and the BEG range. Results were not used if the model fit the data poorly ($\alpha \geq 0.20$) or model assumptions were violated. Hilborn and Walters (1992), Quinn and Deriso (1999), and the Chinook Technical Committee (1999) provide good descriptions of the Ricker model and diagnostics to assess model fit. All stock-recruitment models were tested and corrected for residual autocorrelation when necessary. Additionally, the Ricker alpha parameter was corrected for the logarithm transformation bias induced into the model as described in Hilborn and Walters (1992) from fitting a regression line to ln(recruits/spawners) versus spawners.

Yield Analysis

In previous reviews (Cross et al. 1997, Fair 2000), an empirical approach was used to examine stock-recruitment yield relationships. This approach arranged spawning escapements into intervals. For each escapement interval, we calculated the average escapement and average surplus yield, ASY, for each interval, where yield is recruitment minus parental spawning escapement and

$$ASY = \frac{\sum_{i=1}^{n} y_i}{n}. \quad (1)$$

The problem with this approach is that the arrangement of spawning intervals is highly subjective and often results in large perceived changes in categorical yield.

As an alternative empirical stock-yield approach, yields were first plotted against spawning escapements. Second, the yield and escapement time series were sorted in ascending order by escapement. Next, a running average of n observations of yield, s_i, ($i = 1, \ldots, N\text{-}n\text{+}1$) is defined by

$$s_i = \frac{1}{n} \sum_{j=i}^{i+n-1} a_j , \quad (2)$$

where $a_j = j$th lowest value of yield ($j = 1, \ldots, N$).

Lastly, these new series averages were fit using a nonlinear polynomial of order 2 to approximate a

theoretical yield curve. In this approach, the value of *i* is dependent on the property of the data. In practice, a running average that gives a smooth fit with a parabolic shape is ideal. The advantage of this approach is that the assumptions associated with a Ricker stock-recruitment model are eliminated. However, the underlying theory of stock-recruitment relations remains.

Smolt Information

Smolt production was examined in systems for which this information had been collected. Passage of sockeye salmon smolt has been estimated with hydroacoustic equipment in the Kvichak River since 1971, Egegik River from 1982 through 2001, and Ugashik River from 1983 through 2002, accompanied with age and size data collected from fyke net samples (Crawford and Fair 2003). Relationships between the number of smolt produced (recruitment) and number of spawners were examined using a Ricker stock-recruitment model. If marine survival is assumed to be largely density independent, a smolt production model provides improved estimates of yield related to spawners by eliminating marine environmental influences on survival.

Nushagak District Aggregate Sockeye Salmon Analysis

For the Nushagak District, an additional approach estimated values of MSY for the Igushik, Nushagak, and Wood Rivers by aggregating the catches and escapements for all Nushagak District systems into a single brood table to reduce any potential catch allocation errors from the District's mixed-stock fishery.

Current total run tables include escapement by age for the following components: Igushik River tower, 1956-2002; Nushagak-Mulchatna (NM) River aerial surveys, 1956-2001 with some years missing; Nushagak River sonar, 1989-2001; Nuyakuk River tower, 1956-1988 and 1995-2002 with some years missing; Snake River aerial surveys, 1956-2001 with some years missing; and Wood River tower, 1956-2002. For the period 1956-1989 the total Nushagak District escapement was the sum of Igushik, Nuyakuk, and Wood River tower, and Snake River and NM aerial survey counts; for the period 1990-2001 it was the sum of Wood and Igushik River tower, and Nushagak River sonar.

In the calculation of a Nushagak District aggregate brood table, various contributions to district escapement were found to vary substantially through time. For example, the NM aerial survey averaged 4.5% of the Nushagak District escapements from 1956-1989, while the difference between the Nushagak sonar and Nuyakuk tower (i.e., the surrogate estimate of the NM escapement during the era of sonar) was 11.9% of the Nushagak District escapement. The NM percentage of the Nushagak River is higher during the sonar era, suggesting that earlier estimates based on aerial surveys might be conservative. However, the higher proportion of NM may also be explained by declines in Nuyakuk production during the sonar era. In the aggregate analysis there were no further expansions of the NM aerial counts (Appendix B5).

Average age at maturity during 1968-1988 was used to construct escapement by age for years

with no age data. The Nushagak District total run by age table was augmented by average maturity, leading to a reconstructed aggregate brood table for the Nushagak District.

Standard and autoregressive stock-recruitment Ricker models were fit to estimate MSY and the escapements that produce 90-100% of MSY, which were then allocated to individual stocks (Igushik, Nushagak, and Wood Rivers) based on the average proportion of the total Nushagak District escapement. The proportions used to apportion the aggregate Nushagak District MSY escapement to individual stocks were averaged over the years 1956-2001, and were 17.5%, 21.1%, and 61.4%, for Igushik, Nushagak, and Wood River, respectively. These escapement percentages were remarkably stable over time (Figure 2).

Kvichak River Sockeye Salmon Model

For the Kvichak River sockeye salmon escapement goal analysis, an alternative likelihood ratio test was used to evaluate if pre-peak/peak production is different from off-cycle production. Because a difference existed, the parameters were combined into a single model. A 2-stage model was used, in which the first stage estimated parameters from a Ricker stock-recruitment model for each data set (production cycle). In the second stage, parameters from the best fitting pre-peak/peak and off-cycle models were combined and fit into a single model.

The following hierarchal set of stock recruitment models were fit to the Kvichak River stock-recruitment data for the 1956-1997 brood years. The models were fit using the method of maximum likelihood. The best fit model was selected by a likelihood ratio test. Three likelihood models were fit to the data: a linear model,

$$R = Se^{\alpha}e^{\varepsilon}, \tag{3}$$

where R=recruitment and S=spawning escapement; a standard Ricker model (Ricker 1954),

$$R=Se^{(\alpha(1-S/B))}e^{\varepsilon}; \tag{4}$$

and a first order autoregressive model,

$$R_i = S_i e^{(\alpha(1-S_i/\beta))}e^{\varepsilon_i}, \tag{5}$$

where $\varepsilon_i = \varphi\,\varepsilon_{i-1} + u_i$ and u_i represents independent error distributed normally with mean 0 and variance σ^2.

Pre-peak/peak cycle data (i.e., 1956, 1959, 1960, 1964, 1965, 1969, 1970, 1974, 1975, 1979, 1980, 1984, 1989, 1990, 1994, 1995 brood years) and off-cycle data (1956-1997 other than pre-peak or peak cycle brood years) were fit to each of the three likelihood stock-recruitment models for a total of six models.

Each of the six models was fit to the Kvichak River data using the method of maximum

likelihood. Parameters were selected to maximize the likelihood (L). The log normal error structure was used to derive the likelihood function (L),

$$L = \prod \left[\frac{1}{\sigma\sqrt{2\pi}} e - \frac{\ln\left(\frac{R_i}{\hat{R}_i}\right)}{2\sigma^2} \right]. \quad (6)$$

The models were fit using Excel spreadsheets with the Solver routine to search over the parameter space to minimize the -ln(L), which is equivalent to maximizing L. The α and β parameters of the stock-recruitment models were bias corrected so that α' and β' are unbiased estimates (Hilborn and Walters 1992):

$$\alpha' = \alpha + \sigma^2/2, \text{ and} \quad (7)$$

$$\beta' = \beta\alpha'/\alpha. \quad (8)$$

For the autoregressive model the bias correction is:

$$\alpha' = \alpha + \sigma^2/[2(1-\phi^2)], \text{ where} \quad (9)$$

$$\sigma^2 = \frac{\sum \ln\left(\frac{\hat{R}_i}{S_i}\right)^2}{n-p}, \quad (10)$$

and p = number of parameters in the model. For each model, MSY and the escapements that produce 90-100% of MSY were calculated. The likelihood profile for the MSY escapement goal and the likelihood profiles for the MSY escapement levels were estimated. The MSY escapement levels were based on the bias corrected stock-recruitment parameters. The likelihood profile is the sampling distribution for the MSY escapement goals.

Sustainable Escapement Goal Determination

This was the first time that SEGs were estimated for Bristol Bay stocks based on the SSFP and EGP. The team identified eight salmon stocks from Bristol Bay with SEG-quality data: chinook salmon from the Alagnak, Egegik, Naknek, and Togiak Rivers; coho salmon from Togiak River; chum salmon from the Nushagak River; and sockeye salmon from the Alagnak and Kulukak Rivers. Seven of the eight recommended SEGs are out of compliance with the SSFP (5 AAC 39.222, although the department is currently proposing to amend the SSFP and EGP to

accommodate SEG's expressed as a range or lower bound threshold. Generally, SEGs are used when there is a lack of information on stock productivity. Constraining the escapement goal as a range for these stocks and managing to maintain escapements within that range may hamper future efforts to examine stock productivity and ultimately estimate MSY. The present levels of escapement obviously provide sustainable yields and that level of escapement should continue to do so into the future.

With the exception of the Nushagak River SEG, escapements were estimated from aerial surveys. Nushagak River chum salmon escapements were estimated using hydroacoustics and gillnet catches. Harvest data are available for all stocks where SEG's were developed.

Risk Analysis

For stocks that are passively managed and coincidentally harvested, SEG thresholds were estimated. The seven stocks selected for this procedure were Alagnak, Egegik, Naknek, and Togiak River chinook salmon, Nushagak River chum salmon, and Alagnak and Kulukak River sockeye salmon. Additionally, even though the Nushagak River pink salmon escapement goal was dropped we used the risk analysis approach to estimate a goal in case it is reinstated in the future.

All escapement time series except for Egegik River chinook salmon were composed of a single aggregate count or survey. For Egegik River chinook salmon there were aerial survey data from the mainstem and five tributaries (Sands et al. 2003). Correlation in log-transformed escapements among the six aerial survey areas was not high, but Gertrude, Kaye's and Takayoto Creeks all exhibited positive correlations that exceeded 0.5 and are proximate to each other in the King Salmon River drainage, so that these three systems were combined into one index of escapements for use in the SEG analysis. Counts in these three surveys represent approximately 65% of enumerated chinook salmon in Egegik River surveys.

The method used to develop SEG thresholds followed that of Bernard et al. (*in press*). Escapement time series were first log-transformed and tested for deviations from normality using a one-sample Kolmogorov-Smirov test. The log-transformed escapement time series were then tested for serial correlation using diagnostics in Abraham and Ledolter (1983). Residuals of the four autoregressive models had no significant serial correlation, so no further modeling was necessary.

For Nushagak River pink and chum salmon, and the Egegik and Naknek River chinook salmon stocks, risk of an unwarranted restriction due to a management concern (π_k) was estimated directly from the log transformed mean (μ), standard deviation (σ), and number of consecutive years to warrant a management concern (k) for various values of an escapement threshold (X) as per Bernard et al. (*in press*):

$$\hat{\pi}_k = \left\{ pr\left[(N : \hat{\mu}, \hat{\sigma}^2) \le \ln X \right] \right\}^k, \text{ where k=3.} \qquad (11)$$

For Alagnak and Kulukak River sockeye salmon, and Alagnak and Togiak River chinook salmon, direct calculation of risk of unwarranted restriction was not possible due to autocorrelation in escapements, so that simulation was required. A long escapement time series

was simulated using the original escapements and the appropriate autoregressive model. Simulated escapements were appended onto the original escapement time series, so that a large number of (> 1,000) escapements were available. This allowed for a large number of possible sets of three consecutive years for tabulation of estimated risk. Risk was then estimated by summing the number of times three consecutive years of escapements were below various escapement thresholds dividing by the number of simulated escapements minus four.

Risk of detecting a drop in mean escapement was calculated in the same way as risk of an unwarranted concern, except that the risk of not detecting ($1-\hat{\pi}_k$) was estimated and the mean escapement ($\hat{\mu}$) was changed by the desired percentage drop in mean to be detected with the threshold. Risk was estimated for drops of 95 to 25 percent of the mean escapement depending on the stock. The maximum percentage drop in mean escapement was based on the observed percent difference between the mean escapement and the minimum escapement for each stock (95% for Nushagak River pink and Kulukak River sockeye salmon, 85% for Alagnak River sockeye salmon, 80% for Alagnak River chinook salmon, 70% for Nushagak River chum and Egegik River chinook salmon, 55% for Naknek River chinook salmon, and 40% for Togiak River chinook salmon). Recommended escapement thresholds were chosen based on an estimated risk of 15% or less for triggering an unwarranted management concern and an approximately equal risk of failing to detect the maximum percentage drop in mean escapement as noted above.

Percentile Approach

For Togiak River coho salmon, which are actively managed, an SEG range was developed using the percentile method of Bue and Hasbrouck (2001), whereby the information content of the data was used to modify the percentiles for estimating the SEG range based on the contrast in the escapement data. The contrast is the ratio of the largest escapement to the smallest escapement (Chinook Technical Committee 1999). Low contrast (<4) implies that stock productivity is known for only a limited range of escapements. For stocks with low contrast the SEG should be relatively wide to improve future knowledge of stock productivity. At larger contrast the percentiles used to estimate the SEG were narrowed to allow the SEG to include a wide range of escapements and yields, but not escapements for which yields may be reduced. For stocks with high contrast and at least moderate exploitation, the lower end of the SEG range was increased to the 25th percentile as a precautionary measure for stock protection.

Of note, the percentile approach is equivalent to the risk of an unwarranted management concern for one consecutive year, but the risk of undetected drops is not calculated. The principle of the percentile approach is that yields have been sustained and will continue to be sustained with escapements that vary around the observed average.

RESULTS

There were 21 escapement goals evaluated for 20 stocks. Of the 17 existing goals, 11 were

changed, three remained unchanged, and three were dropped (Table 4). In addition, a goal was recommended for four stocks that previously did not have a goal. Appendices A–E document the escapement goal of each stock.

Biological Escapement Goals

Chinook Salmon

Nushagak River

The BEG of 65,000 chinook salmon counted by sonar changed to a range of 40,000 to 80,000 such fish. Ricker stock-recruitment models were fit with two data sets of escapement: (1) sonar data from 1980 to present, and (2) a full data set that includes expanded aerial surveys (1966-1979) and sonar. Because the results from both models were nearly identical, we used the full data set in our final analysis to better encompass long-term variability. The full model fit to the data for 1966-1996 brood years had autocorrelation of lag-1 and estimated escapement that produced MSY (S_{MSY}) at 50,000 spawners with a 90-100% MSY escapement range of 32,000 to 71,000 (Table 5, Appendix A1). The stock-yield model estimated S_{MSY} at 85,000 spawners with a 90-100% MSY escapement range of 58,000 to 112,000 spawners. The recommended range was based on the combined results from the Ricker and stock-yield models.

The trend towards younger fish in chinook salmon spawning escapements from 1995-1997 previously raised concerns about the quality of chinook salmon escapements into the Nushagak River. Chinook salmon size and sex composition varies greatly with the smaller three and four-year-old chinook salmon returning to spawn primarily as males. The age-5 through age-7 Ricker stock-recruitment model estimated that 41,000 age-5 through age-7 spawners would produce MSY. Based on this, a BEG of 40,000 to 80,000 should address spawner quality adequately.

Sockeye Salmon

Egegik River

The BEG of 800,000 to 1,400,000 spawners changed to a range of 800,000 to 2,000,000 spawners. A Ricker stock-recruitment model fit to the data for 1956-1997 brood years had autocorrelation of lag-1 and estimated S_{MSY} at 3,533,000 with a 90-100% MSY escapement range of 1,732,000 to 15,130,000 (Table 5, Appendix B1). This model was fit with a Bayesian approach that incorporated a prior that constrained the β parameter to positive values because the relationship shows no significant density dependence. Additionally, a Ricker stock-smolt model fit to the data for 1976-1997 brood years estimated S_{MSY} at 1,553,000 spawners with a 90-100% MSY escapement range of 949,000 to 2,361,000. The stock-yield model could not estimate S_{MSY} because there was no discernable peak. Instead, the raw data was fit with an S-Plus Super Smoother function (Venables and Ripley 1994) that showed yields were greatest at escapements larger than approximately 1,100,000.

The smolt model had the most weight in determining an escapement goal range because if marine survival is assumed to be largely density independent, which is the current belief, then a smolt production model should provide the best estimates of yield related to spawners. All of the models suggested that the upper goal should be raised but the lower goal was more difficult to determine.

The smolt model had a lower 90% MSY escapement range that was below 1.0 million with good yields from all escapements in the model (down to 700 thousand). Escapements near the existing lower goal of 800 thousand spawners have not occurred since 1983 and it was associated with a large return (greater than 10 million fish). Most escapements less than 900,000 occurred during the less productive 1960s and 1970s. It is uncertain what the magnitude of returns would be in the current production regime at escapements near the lower end of the goal. The uncertainty of current production at escapements between 800,000 and 1,000,000 coupled with the smolt model results, lead the committee to leave the existing lower escapement goal range intact so as not to exclude these escapement levels from the range of acceptable number of spawners.

Models using the more recent and productive (i.e., greater return per spawner) 1976-1997 data set were examined. Similar to the results from the full data set, there was support for an increase in the upper range of the escapement goal. Only the findings from the full data set are provided in this report because the committee felt that whenever possible, models should incorporate all of the available data to best represent inherent long-term variability.

Igushik River

The BEG of 150,000 to 300,000 spawners changed to a range of 200,000 to 450,000 spawners. A Ricker stock-recruitment model fit to the data for 1956-1997 brood years had autocorrelation of lag-1 and estimated S_{MSY} at 441,000 spawners with a 90-100% MSY escapement range of 280,000 to 630,000 (Table 5, Appendix B2). When the 1980 datum was excluded from the Ricker model, all estimates of S_{MSY} were reduced. The stock-yield model without the 1980 datum estimated S_{MSY} at 318,000 spawners with a 90-100% MSY escapement range of 192,000 to 442,000 spawners; these results were nearly identical to those of the Ricker model without 1980. The Nushagak District aggregate analysis with an autoregressive lag-1 Ricker model estimated S_{MSY} at 374,000 spawners with a 90-100% MSY escapement range of 240,000 to 527,000.

Because the 1980 escapement of almost 2 million fish is more than double the next largest observed escapement it has a large influence in estimating MSY. When the Ricker stock-recruitment model was run without the 1980 data point, MSY estimates were smaller than the full data set but nonetheless, supported raising the lower and upper ranges of the goal. The lower and upper ranges were determined as a compromise between model results from Ricker with and without 1980, the stock-yield relationship, and the Nushagak District aggregate approach.

Kvichak River

For the off-cycle years, the BEG of 2,000,000 to 10,000,000 spawners did not change. For the pre-peak and peak years, the BEG of 6,000,000 to 10,000,000 spawners changed to a range of 6,000,000 to 17,000,000 spawners. Previous analyses have separated the off-cycle data from the pre-peak/peak years because it was believed that their productivity differed. This difference in productivity became apparent in a 2-stage autoregressive lag-1 Ricker stock-recruitment model fit to the data for 1956-1997 brood years that for off-cycle years estimated S_{MSY} at 4,862,000 spawners with a 90-100% MSY escapement range of 3,208,000 to 6,643,000; for pre-peak/peak years S_{MSY} was 16,182,000 spawners with a 90-100% MSY escapement range of 10,653,000 to 22,503,000 (Table 5, Appendix B3).

The 2-stage model, the straight Ricker model (S_{MSY}=3,059,000), and the stock-yield model (S_{MSY}=3,033,000) each estimated S_{MSY} values that were within the current escapement goal range

for off-cycle production. The same analyses (straight Ricker: S_{MSY}=12,076,000; stock-yield: S_{MSY}=13,533,000) applied to the pre-peak/peak data estimated S_{MSY} greater than the current upper escapement goal range, prompting an increase in the upper range to 17 million spawners. A Ricker stock-smolt model was significant for only the pre-peak/peak data set, and similar to other models, estimated S_{MSY} at 13,424,000 spawners.

Naknek River

The BEG of 800,000 to 1,400,000 spawners changed to a range of 1,000,000 to 2,000,000 spawners. A Ricker stock-recruitment model fit to the data for 1956-1997 brood years estimated S_{MSY} at 2,070,000 spawners with a 90-100% MSY escapement range of 1,336,000 to 2,906,000 (Table 5, Appendix B4). The stock-yield model without the 1986 outlier, estimated S_{MSY} at 1,746,000 spawners with a 90-100% MSY escapement range of 1,194,000 to 2,298,000 spawners. Both approaches estimate that MSY is greater than the upper range of the current goal, and additionally the lower 90-100% MSY ranges are significantly greater than the lower range of the current goal. Therefore, both the lower and upper escapement goal ranges were raised. Although there is evidence suggesting that the upper goal could be set at a level greater than 2.0 million, the committee refrained because of the limited number (and hence, uncertainty) of escapements above this level and that return data from some recent large (> 1.5 million in 1999 and 2001) escapements is forthcoming.

Nushagak River

The BEG of 340,000 to 760,000 spawners did not change. A Ricker stock-recruitment model fit to the data for 1978-1997 brood years estimated S_{MSY} at 799,000 spawners with a 90-100% MSY escapement range of 516,000 to 1,120,000 (Table 5, Appendix B5). Without the 1980 datum in the Ricker model, S_{MSY} was reduced to 578,000 spawners with a 90-100% MSY escapement range of 371,000 to 819,000. The stock-yield model without 1980 estimated S_{MSY} at 568,000 spawners with a 90-100% MSY escapement range of 389,000 to 748,000 spawners. With the 1980 data point removed, Nushagak River escapement has the least contrast (Table 5) of the sockeye salmon BEG systems. The 1980 data point is very influential in the Ricker model results so it was run with and without this datum.

The Nushagak District aggregate analysis with an autoregressive lag-1 Ricker stock-recruitment model estimated S_{MSY} at 451,000 spawners with a 90-100% MSY escapement range of 290,000 to 636,000. Results from the Ricker and stock-yield models without 1980 were similar. However, because they differed significantly from the conflicting results of the full Ricker model and the Nushagak District aggregate analysis, the committee found no compelling evidence to change the existing goal.

Togiak River

The BEG of 100,000 to 200,000 spawners changed to a range of 100,000 to 250,000 spawners. A Ricker stock-recruitment model fit to the data for 1956-1997 brood years had autocorrelation of lag-1 and estimated S_{MSY} at 187,000 spawners with a 90-100% MSY escapement range of 119,000 to 267,000 (Table 5, Appendix B6). The stock-yield model estimated S_{MSY} at 206,000 spawners with a 90-100% MSY escapement range of 151,000 to 262,000 spawners.

Both the Ricker and stock-yield models estimated that S_{MSY} is near the upper end of the current goal, prompting us to raise the upper range. An upper range of 250,000 was chosen because it

closely matches the upper 90-100% MSY escapement range from both approaches. Because the aerial survey escapement component is additional to the Togiak River tower counts, and annually averages 20,000 expanded counts, it was added to the river BEG of 100,000 to 250,000 spawners for a total Togiak River system goal of 120,000 to 270,000 spawners.

Ugashik River
The BEG of 500,000 to 1,200,000 spawners changed to a range of 500,000 to 1,800,000 spawners. Stock-recruitment models were used for two periods of productivity, the full 1956-1997 brood year data set and a more recent 1974-1997 data set. The committee felt that the more recent data set best represented current productivity, so more weight was placed on the results from this time period in our escapement goal evaluation.

A Ricker stock-recruitment model fit to the data for 1974-1997 brood years had autocorrelation of lag-1 and estimated S_{MSY} at 1,287,000 spawners with a 90-100% MSY escapement range of 811,000 to 1,862,000 (Table 5, Appendix B7). A Ricker stock-recruitment relationship was also examined without the large 1980 escapement, and found that S_{MSY} dropped down to 1,063,000. A Ricker stock-smolt model was not significant ($p = 0.36$).

The stock-yield model estimated S_{MSY} at 1,644,000 spawners with a 90-100% MSY escapement range of 1,124,000 to 2,164,000 spawners. Both approaches estimate that S_{MSY} is greater than the upper range of the current goal, prompting us to raise the upper end. Although there is evidence from the MSY models to raise the lower goal, in the 1974-1997 data set there is little difference in yield throughout the observed spawning escapements. Therefore, the committee decided to maintain a lower range of 500,000 while raising the upper escapement goal range.

Wood River
The BEG of 700,000 to 1,500,000 spawners did not change. A Ricker stock-recruitment model fit to the data for 1956-1997 brood years had autocorrelation of lag-1 and estimated S_{MSY} at 1,061,000 spawners with a 90-100% MSY escapement range of 681,000 to 1,499,000 (Table 5, Appendix B8). A Ricker model using the more productive recent years (brood years 1972-1997) gave nearly identical results (S_{MSY}=1,041,000) as the full data set. The stock-yield model estimated S_{MSY} at 1,425,000 spawners with a 90-100% MSY escapement range of 1,054,000 to 1,796,000 spawners. The Nushagak District aggregate analysis with an autoregressive lag-1 Ricker model estimated S_{MSY} at 1,311,000 spawners with a 90-100% MSY escapement range of 843,000 to 1,849,000. All of the models support the existing goal, which has remained remarkably stable since the 1960s.

Sustainable Escapement Goals

With the exception of Togiak River coho salmon, the risk analysis approach (Bernard et al. *in press*) was applied to all sustainable escapement goals. None of the tested time series deviated significantly from log-normal distributions (for all seven stocks $p > 0.07$). There was significant (α=0.05) serial correlation in escapements of Alagnak and Togiak River chinook salmon (lag 1) and Alagnak and Kulukak River sockeye salmon (lag 4 and lags 1 and 2, respectively). Escapements of Nushagak River chum salmon and Egegik and Naknek River chinook salmon were modeled as log-normally distributed variables; Alagnak River sockeye salmon was modeled with a lag-4

autoregressive term; and Kulukak River sockeye salmon and Alagnak and Togiak River chinook salmon were modeled with a lag-1 autoregressive term.

Chinook Salmon

Alagnak River

The committee established a lower bound SEG of 2,700 aerial survey counts with no upper bound using the risk analysis approach. Using escapement data since 1970, an escapement threshold of 2,700 resulted in a 10% estimated risk of an unwarranted concern, with a 9% estimated risk that a drop in mean escapement of 80% would not be detected for three years (Table 6; Appendix A2). The desire is to maintain the average escapement at 5,000 aerial survey units.

Egegik River

The committee established a lower bound SEG of 450 aerial survey counts with no upper bound using the risk analysis approach. Escapement data of Egegik River chinook salmon beginning in 1985 are the sum of aerial surveys from Gertrude, Kaye's, and Takayota creeks only. An escapement threshold of 450 resulted in a 4% estimated risk of an unwarranted concern, with a 4% estimated risk that a drop in mean escapement of 70% would not be detected for three years (Table 6; Appendix A3). The desire is to maintain the average escapement at 600 aerial survey units.

Naknek River

The BEG of 5,000 aerial survey counts changed to a lower bound SEG of 5,000 aerial survey counts with no upper bound. The goal was estimated using the risk analysis approach with escapement data beginning in 1971. An escapement threshold of 4,900 resulted in a 10% estimated risk of an unwarranted concern, with a 9% estimated risk that a drop in mean escapement of 60% would not be detected across three years (Table 6; Appendix A4). These threshold values are very near to and encompass the current escapement goal of 5,000. In addition, Sport Fish Division is currently conducting an assessment project to provide more information on chinook salmon escapement into the Naknek River and will re-evaluate this escapement goal before the next regularly scheduled Bristol Bay Board of Fish meeting. The desire is to maintain the average escapement at 5,600 aerial survey units.

Togiak River

The BEG of 10,000 spawners changed to a lower bound SEG of 9,300 spawners with no upper bound. The goal was estimated using the risk analysis approach with escapement data beginning in 1980. An escapement threshold of 9,300 resulted in a 15% estimated risk of an unwarranted concern, with a 15% estimated risk that a drop in mean escapement of 40% would not be detected over three years (Table 6; Appendix A5). The desire is to maintain the average escapement at 10,100 fish assessed by aerial survey. Although this system has escapement and harvest information, it is inadequate for a BEG because the escapement data has a low contrast and there are large measurement errors associated with the aerial surveys.

Chum Salmon

Nushagak River

The committee established a lower bound SEG of 190,000 sonar counts with no upper bound

using the risk analysis approach. This goal applies to escapement estimates through July 20, the final day that the sonar will be in operation in future years. Using escapement data since 1979, an escapement threshold of 190,000 resulted in a 6% estimated risk of an unwarranted concern, with a 6% estimated risk that a drop in mean escapement of 70% would not be detected over three years (Table 6; Appendix C1). The desire is to maintain the average escapement at 246,000 sonar counts. Although the data for this system is similar to that of Nushagak River chinook and sockeye salmon, the difference is that chum salmon are not actively managed in the Nushagak. For this reason, the goal was set using an SEG risk analysis approach.

Coho Salmon

Togiak River

The BEG of 25,000 to 75,000 spawners changed to a SEG range of 21,000 to 63,000 spawners using the percentile approach of Bue and Hasbrouck (2001) with 1980-2002 escapement data (Appendix D1). Eight aerial surveys were missing since the first survey in 1980. In an attempt to build a brood table and estimate MSY, missing escapements were estimated using the relationship between Togiak River coho escapement and (1) Togiak River catch, and (2) Nushagak River coho total run. All fish were assumed to be fours years of age. A Ricker stock-recruitment model was fit to the data but the slope was not significant ($p = 0.68$).

Sockeye Salmon

Alagnak River

The BEG of 170,000 to 200,000 aerial survey counts changed to a lower bound SEG of 100,000 aerial counts with no upper bound. The goal was estimated using the risk analysis approach with escapement data beginning in 1956 (Table 6; Appendix B9). An escapement threshold of 100,000 resulted in a 13% estimated risk of an unwarranted concern, with a 13% estimated risk that a drop in mean escapement of 65% would not be detected in three years. The desire is to maintain the average escapement at 260,000 aerial survey units.

Although a full brood table exists for this stock, the committee felt that the escapement data, which is largely composed of aerial surveys (1977-2001), was of insufficient quality to estimate MSY. Additionally, tower data collected from 1956-1976 was poor due to the tower's location in the intertidal zone with frequent murky water conditions.

Kulukak Bay

The committee established a lower bound SEG of 8,000 aerial survey counts with no upper bound using the risk analysis approach with escapement data beginning in 1961 (Table 6; Appendix B10). An escapement threshold of 8,000 resulted in a 5% estimated risk of an unwarranted concern, with a 5% estimated risk that a drop in mean escapement of 90% would not be detected in three years. The desire is to maintain the average escapement at 22,000 aerial survey units.

Dropped Escapement Goals

Coho Salmon

Nushagak River

The BEG of 50,000 to 100,000 spawners was dropped because escapement is no longer assessed. In 2003 due to budget cuts, the Nushagak River sonar project was shortened in duration from August 17 to July 20, thereby missing the majority of the coho and pink salmon run. An assessment of all available data however, indicated that if the escapement goal were to remain in effect, it would not change. A Ricker stock-recruitment model fit to the data for 1980-1997 brood years estimated escapement S_{MSY} at 81,000 spawners with a 90-100% MSY escapement range of 53,000 to 111,000 (Table 5, Appendix D2). The stock-yield model estimated S_{MSY} at 85,000 spawners with a 90-100% MSY escapement range of 58,000 to 111,000 spawners.

Kulukak River

The BEG of 15,000 spawners was dropped because no fishery management decisions have been made for this stock, weather conditions often hamper completing the aerial surveys, and it is highly unlikely that escapement surveys will be flown in the future due to budget reductions (Appendix D3). Thus, we did not conduct an escapement goal analysis for this stock.

Pink Salmon

Nushagak River

The BEG of 600,000 to 1,100,000 spawners was dropped because escapement is no longer assessed as discussed for Nushagak River coho salmon above. However, an assessment of escapement data since 1958 using the risk analysis approach indicated that an escapement threshold of 280,000 has a 10% estimated risk of an unwarranted concern, with a 9% estimated risk that a drop in mean escapement of 95% would not be detected over three years. If the escapement goal remained in effect, it would change to a lower bound SEG of 280,000 with no upper bound (Table 6; Appendix E1).

DISCUSSION

In this review, many of the escapement goals were changed. In particular, most BEGs increased on the upper end of the range while some changed on the lower range as well. For many of the systems, there has been evidence to raise the goal for 10-15 years but without policies such as the SSFP or EGP in place, there was reluctance to raise the goal because of public outcry. In the short term, with an increase in a goal there is a loss in catch to the fishery because more fish are put on the spawning grounds. Down the road however, providing that productivity is stable, yields will be at or near MSY, allowing for a larger catch.

Estimating escapement goals is an evolving process, not only because each year provides more data but also because approaches to estimate goals are increasingly becoming more standardized and documented. The SSFP and EGP are important steps in this evolution. Ideally, escapement

goals should be based in part on ecological theory, principles of sustained yield, and observations (Ricker 1954, Caughley 1977).

The department recently formed an Escapement Goal Policy Implementation Team (EGPIT), whose efforts should provide recommendations on the estimation of escapement goals. EGPIT and other such groups will hopefully provide a more theoretical framework to estimate escapement goals, especially SEG ranges and thresholds.

The methodology of this escapement goal evaluation varied from previous reviews in many respects. For the Ricker stock-recruitment models, we tested for autocorrelation of the residuals, and when necessary made the proper corrections (Chinook Technical Committee 1999). Additionally, the alpha parameter was corrected for the logarithm transformation bias induced into the model by the estimation process (Hilborn and Walters 1992). In the 2000 escapement goal review (Fair 2000), a greater focus was put on a bootstrapped confidence interval in setting a range around S_{MSY}, whereas in this review the 90-100% MSY escapement range was deemed a better tactic. The analysis of spawner-yield data also changed from previous evaluations. Historically, average yields were grouped and evaluated by spawning interval as either a histogram or yield table, similar to the Markov probability table of Hilborn and Walters (1992). In this evaluation, the committee's desire to avoid the subjective setting of escapement intervals prompted us to focus more on the raw data portrayed in a scatter plot of spawners and yield.

For the Kvichak and Nushagak Rivers, innovative approaches to estimating S_{MSY} were developed. The Kvichak River has a strong cycle in production with two large returns followed by three smaller returns. A 2-stage Ricker stock-recruitment model first tested for differences in production between the two cycles and then combined each cycle's parameters into a single model. The committee supported this approach because it accounts for the autoregressive nature of the data in a way that dividing the cycle data into two data sets and individually estimating S_{MSY} could not. In the Nushagak District, to avoid potential brood table errors associated with misallocation of the catch, data from Igushik, Nushagak, and Wood Rivers were aggregated into a single brood table for stock-recruitment analysis. Once S_{MSY} for the Nushagak District was estimated, it was divided by river system based on historical escapement proportions. The committee felt this was a valid approach that could be applied elsewhere as alternative estimates of S_{MSY}.

For SEGs, the definition does not require that escapements are distributed throughout the range. The committee did not want to see all future escapements concentrated towards the lower end of the SEG range, and recommended that the average escapement for future years reflect the present average escapement.

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Table 1. Bristol Bay sockeye salmon runs by system, 1993-2002 (in thousands of fish).

Year	Alagnak	Egegik	Igushik	Kvichak	Naknek	Nushagak	Togiak	Ugashik	Wood	Total
1993	868	24,482	1,662	9,902	4,906	2,330	697	5,913	3,936	54,696
1994	656	12,999	1,380	22,735	3,144	1,618	522	5,605	3,111	51,770
1995	675	16,201	1,990	28,330	3,700	792	771	6,041	4,192	62,692
1996	724	12,253	1,514	3,538	7,076	1,804	586	5,237	5,159	37,893
1997	266	9,363	314	1,828	1,515	930	264	2,239	3,631	20,350
1998	412	5,090	614	3,554	2,747	941	314	1,786	4,143	19,602
1999	1,079	9,407	1,627	13,308	3,970	992	565	4,060	6,160	41,167
2000	774	8,403	1,813	3,031	4,935	1,529	1,127	2,300	5,544	29,456
2001	411	3,868	1,324	1,436	6,684	2,126	1,109	1,356	4,014	22,328
2002	793	5,840	214	728	2,775	663	406	2,564	3,842	17,825
Average	**666**	**10,791**	**1,245**	**8,839**	**4,145**	**1,373**	**636**	**3,710**	**4,373**	**35,778**

Table 2. List of individuals from the 2003 Bristol Bay escapement goal committee and other participants.

Name	Affiliation
Escapement Goal Committee:	
James Browning	ADF&G, Division of Commercial Fisheries
Brian Bue	ADF&G, Division of Commercial Fisheries
Robert Clark	ADF&G, Sport Fish Division
Doug Eggers	ADF&G, Division of Commercial Fisheries
Lowell Fair	ADF&G, Division of Commercial Fisheries
Nancy Gove	ADF&G, Division of Commercial Fisheries
James Hasbrouck	ADF&G, Sport Fish Division
Craig Scwanke	ADF&G, Sport Fish Division
Other Participants:	
Drew Crawford	ADF&G, Division of Commercial Fisheries
Steve Fleischman	ADF&G, Sport Fish Division
Stephen Fried	United States Fish and Wildlife Service
Michael Link	Bristol Bay Science and Research Institute
Slim Morstad	ADF&G, Division of Commercial Fisheries
Dave Nelson	National Park Service
Jeff Regnart	ADF&G, Division of Commercial Fisheries
Tim Sands	ADF&G, Division of Commercial Fisheries
Corey Scwanke	ADF&G, Division of Commercial Fisheries
Keith Weiland	ADF&G, Division of Commercial Fisheries
Fred West	ADF&G, Division of Commercial Fisheries

Table 3. General criteria used to assess quality of data in estimating escapement goals of Bristol Bay salmon stocks.

Data Quality	Criteria
Excellent	Escapement, harvest and age all estimated with relatively good accuracy and precision (i.e., escapement estimated by a weir or hydroacoustics, harvest estimated by Statewide Harvest Survey of Fish Tickets); escapement and return estimates can be derived for a sufficient time series to construct a brood table and estimate MSY.
Good	Escapement, harvest and age estimated with reasonably good accuracy and/or precision (i.e., escapement estimated by capture-recapture experiment or multiple foot/aerial surveys); no age data or data of questionable accuracy and/or precision; data may allow construction of brood table; data time series relatively short to accurately estimate MSY.
Fair	Escapement estimated or indexed and harvest estimated with reasonably good accuracy but precision lacking for one if not both; no age data; data sufficient to estimate total return and construct brood table.
Poor	Escapement indexed (i.e., single foot/aerial survey) such that the index provides a fairly reliable measure of escapement; no harvest and age data.

Table 4. Summary of escapement goals for Bristol Bay salmon stocks.

System	Current Goal		Recommended Goal			
	Goal	Year Adopted	Type	Range	Escapement Data	Action
Chinook Salmon						
Nushagak	65,000	1992	BEG	40,000-80,000	Sonar Count	Change
Naknek	5,000	1994	SEG	5,000 minimum	Aerial Survey	Change
Alagnak			SEG	2,700 minimum	Aerial Survey	New Goal
Togiak	10,000	1991	SEG	9,300 minimum	Aerial Survey	Change
Egegik			SEG	450 minimum	Aerial Survey	New Goal
Sockeye Salmon						
Ugashik	500,000-1,200,000	1997	BEG	500,000-1,800,000	Tower Count	Change
Egegik	800,000-1,400,000	1997	BEG	800,000-2,000,000	Tower Count	Change
Kvichak (off-cycle)	2,000,000-10,000,000	1997	BEG	2,000,000-10,000,000	Tower Count	Status Quo
Kvichak (pre and peak)	6,000,000-10,000,000	1997	BEG	6,000,000-17,000,000	Tower Count	Change
Naknek	800,000-1,400.000	1984	BEG	1,000,000-2,000,000	Tower Count	Change
Igushik	150,000-300,000	2000	BEG	200,000-450,000	Tower Count	Change
Wood	700,000-1,500,000	2000	BEG	700,000-1,500,000	Tower Count	Status Quo
Nushagak	340,000-760,000	1997	BEG	340,000-760,000	Sonar Count	Status Quo
Togiak	100,000-200,000 [a]	1997	BEG	120,000-270,000 [b]	Tower and Aerial Survey	Change
Alagnak	170,000-200,000	1973	SEG	100,000 minimum	Aerial Survey	Change
Kulukak Bay			SEG	8,000 minimum	Aerial Survey	New Goal
Chum Salmon						
Nushagak			SEG	190,000 minimum thru July 20	Sonar count	New Goal
Coho Salmon						
Togiak	25,000-75,000	1986	SEG	21,000-63,000	Aerial count	Change
Nushagak	50,000-100,000	1992			Sonar Count	Dropped
Kulukak	15,000	1986			Aerial Count	Dropped
Pink Salmon						
Nushagak	600,000-1,100,000	1992			Sonar Count	Dropped

[a] Current goal is tower counts only
[b] Recommended goal is an inriver goal evaluated by a combination of tower and aerial surveys. Recommended tower goal is 100,000-250,000 fish.

Table 5. Estimates of Ricker stock-recruitment parameters (ln(α), β, ϕ, σ) and derived quantities (S_{eq}, S_{MSY}, R_{MSY}, MSY, 90% S_{MSY} range) for salmon stocks in Bristol Bay, Alaska. Numbers of fish in thousands.

		Current BEG				β								90% S_{MSY} range	
Stock / Data	n[a]	lower	upper	Contrast	ln(α)[b]	Estimate	P-value	ϕ[c]	σ[d]	S_{eq}	S_{MSY}	R_{MSY}	MSY	lower	Upper
Nushagak Chinook	31	65	NA	6.5	1.856	0.000014	<0.01	0.487	0.202	129	50	178	128	32	71
Nushagak Coho	17	50	100	13.8	0.946	0.000005	0.16	NA	0.275	185	81	138	57	53	111
Egegik Sockeye	42	800	1,400	11.3	1.777	0.000207	0.16	0.683	0.310	8,585	3,533	13,442	9,909	1,732	15,130
Smolt	18	800	1,400	4.0	4.440	0.000001	<0.01	-0.537[e]	0.275	7,079	1,553	60,330	58,777	949	2,361
Igushik Sockeye	42	150	300	124.3	1.497	0.001600	<0.01	0.540	0.607	936	441	1,493	1,052	280	630
Aggregate Model	40	150	300	17.1	1.512	0.000294	<0.01	0.635	0.156	900	374	1,005	631	240	527
Kvichak Sock. Off-cycle	23	2,000	6,000	26.7	1.156	0.000159	0.20	NA	0.822	7,253	3,059	5,968	2,908	1,999	4,228
2-Stage	42	2,000	10,000	107.2	0.540	0.000081	0.01[f]	0.467	0.520	6,698	4,862	7,999	3,137	3,208	6,643
Kvichak Sock. Pre-peak/Peak	15	6,000	10,000	25.4	1.540	0.000050	0.16	NA	0.506	30,651	12,076	30,702	18,625	7,779	16,980
2-Stage	42	2,000	10,000	107.2	0.937	0.000033	0.01[f]	0.467	0.520	28,576	16,182	34,468	18,286	10,653	22,503
Smolt	12	6,000	10,000	4.0	4.008	-7.10E-08	0.09	NA	0.198	56,465	13,424	284,900	271,476	8,232	20,273
Naknek Sockeye	42	800	1,400	12.9	1.495	0.000287	0.03	NA	0.290	5,212	2,070	5,100	3,029	1,336	2,906
Nushagak Sockeye	20	340	760	11.8	1.464	-0.000732	<0.01	NA	0.151	2,000	799	1,924	1,125	516	1,120
Without 1980 datum	19	340	760	3.6	1.680	-0.001115	0.04	NA	0.154	1,507	578	1,629	1,050	371	819
Aggregate Model	40	340	760	17.1	1.512	0.000294	<0.01	0.635	0.156	1,086	451	1,212	761	290	636
Togiak Sockeye	42	100	200	21.1	1.723	0.003700	<0.01	0.282	0.270	466	187	607	420	119	267
Ugashik Sockeye	24	500	1,200	53.8	2.025	0.000600	<0.01	0.526	0.328	3,376	1,287	5,651	4,364	811	1,862
Wood Sockeye	42	700	1,500	10.3	1.523	0.000600	<0.01	0.487	0.193	2,538	1,061	2,920	1,859	681	1,499
Aggregate Model	40	700	1,500	17.1	1.512	0.000294	<0.01	0.635	0.156	3,156	1,311	3,524	2,213	843	1,849

[a] Number of years of escapement data.
[b] ln(a) is adjusted for non-zero expectation of ln(residuals)
[c] Autoregressive parameter estimate at lag-1 if correlation of residuals was significant; otherwise, term is not applicable (NA).
[d] Variance, or mean square error of the model.
[e] Autoregressive parameter estimate at lag-2.
[f] Except for the Kvichak 2-stage model, the p-value shows the significance of the density dependence term; in this case it shows the significance of the autoregressive term, ϕ.

Table 6. Estimates of risk analysis parameters and SEG thresholds for salmon stocks in Bristol Bay, Alaska.

Stock / Data	n[a]	Current Goal	Min	Max	Contrast	Mean	Standard Deviation	ϕ[b]	SEG Threshold	Risk (Percent)		
										Unwarranted Concern	Not Detecting a Drop in Mean Esc	Percent Drop in Mean Esc
Alagnak Chinook	33	NA	824	15,210	18.5	4,982	3,384	0.537 - lag 1	2,700	10	9	80
Egegik Chinook	15	NA	199	924	4.6	585	221	NA	450	4	4	70
Naknek Chinook	26	5,000	2,536	11,730	4.6	5,579	2,638	NA	5,000	10	9	60
Togiak Chinook	22	10,000	6,390	19,085	3.0	10,098	3,168	0.383 - lag 1	9,300	15	15	40
Nushagak Chum	24	NA	59,869	509,436	8.5	246,042	181,010	NA	190,000	6	6	70
Nushagak Pink	22	600,000-1,000,000	58,536	9,161,784	156.5	1,364,297	2,044,279	NA	280,000	10	9	95
Alagnak Sockeye	47	170,000-200,000	35,000	1,241,000	35.5	260,000	224,000	0.410 - lag 4	100,000	13	13	65
Kulukak Sockeye	41	NA	800	58,780	73.5	22,443	15,370	0.720 - lags 1 & 2	8,000	5	5	90

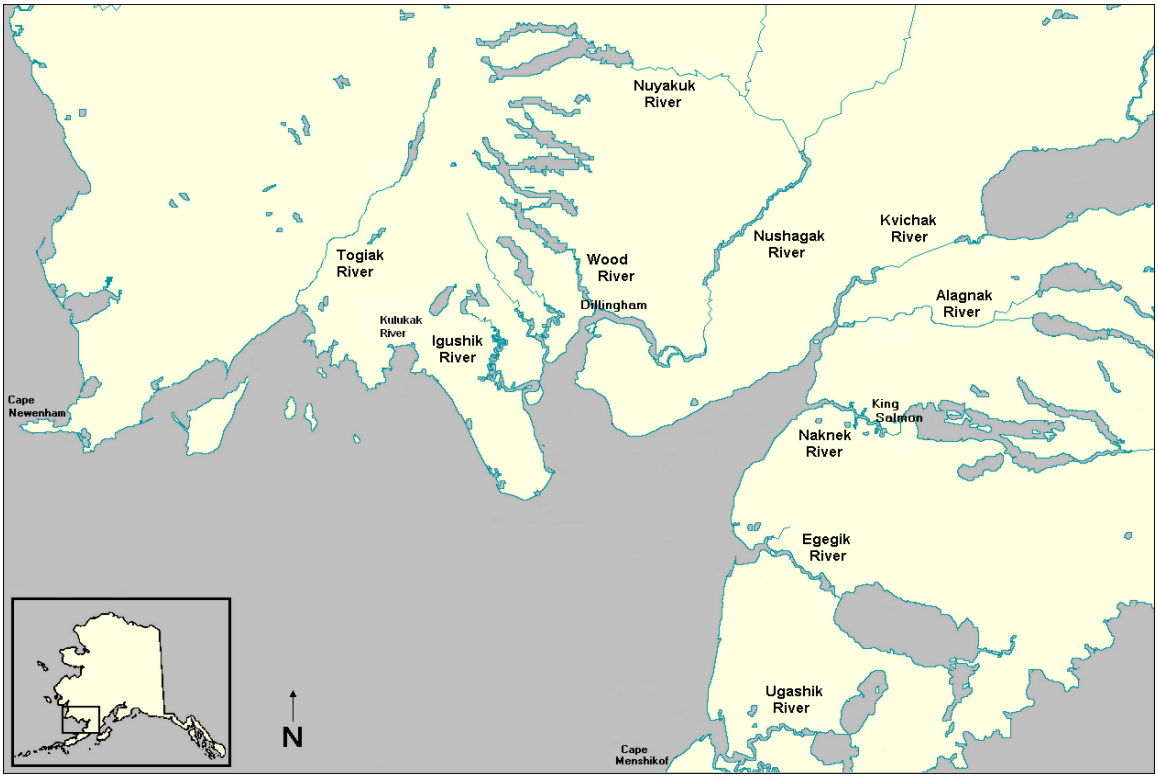


Figure 1. Map of Bristol Bay showing major salmon rivers.

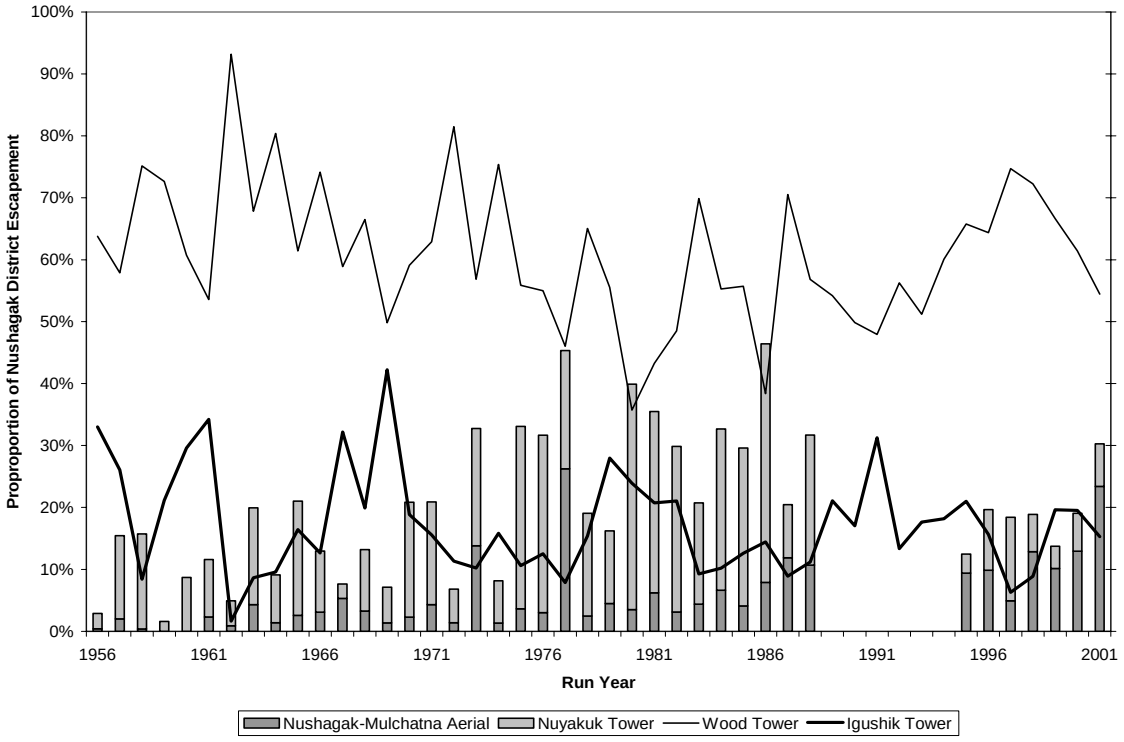


Figure 2. Variation in Nushagak District sockeye salmon escapement components, 1956 – 2001.

APPENDIX A.
SUPPORTING INFORMATION FOR CHINOOK SALMON ESCAPEMENT GOALS OF BRISTOL BAY

Appendix A1. – Escapement goal for Nushagak River chinook salmon.

System: **Nushagak River**
Species: **chinook salmon**

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	65,000 (1992)
Inriver Goal:	75,000
Optimal Escapement Goal:	None
Recommended Escapement Goal:	40,000 – 80,000
Escapement Goal Type:	BEG
Escapement Estimation:	Expanded aerial survey counts plus Nuyakuk tower from 1966-1979; sonar counts from 1980 to present; 31 years of complete return data available
Summary:	
Data Quality	Good
Data Type	Aerial survey, tower, and sonar escapement estimates; sport, subsistence, and commercial harvests; age data
Methodology	Ricker stock-recruitment, yield analysis
Autocorrelation	Significant autoregressive correlation at lag-1
Years within recommended goal	15 out of 31
Comments	The analysis was conducted using years for which complete return data were available (1966-1996); sonar data only (1980-1996) gave similar estimates of S_{MSY}. In this review, we established an escapement goal range. The goal represents an estimate of total spawner abundance.

Appendix A1. – Continued.

System: Nushagak River
Species: chinook salmon

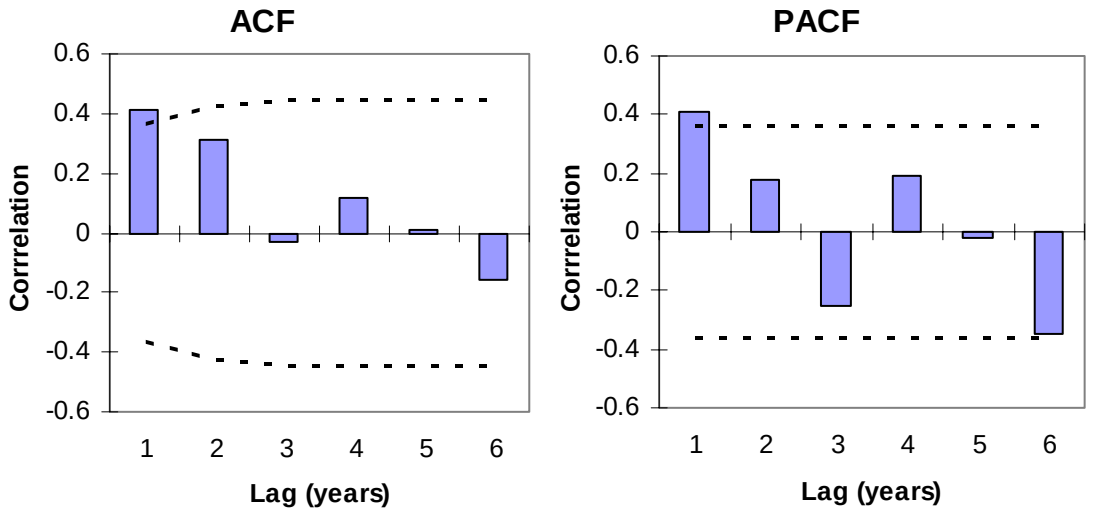
Data available for analysis of escapement goals.

Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	0.5	1.4	2.3	1.5	2.4	1.6	2.5	Total Return
1966	40,000	149	62	7,406	13,979	0	4,668	27,454	0	0	38,557	130	5,044	376	1,043	342	99,210
1967	65,000	0	0	283	9,795	0	1,575	16,353	76	188	46,066	380	24,552	342	275	0	99,885
1968	70,000	0	0	834	13,485	0	376	18,291	0	0	67,765		8,368	542	0	0	109,661
1969	35,000	230	0	384	965	0	0	14,524	0	0	29,429	808	2,430	268	0	0	49,038
1970	50,000	0	0	0	1,385	0	0	56,699	0	0	73,517	1,323	4,043	874	0	847	138,688
1971	40,000	0	0	0	2,433	0	389	55,755	501	0	94,828	1,266	12,572	6,976	0	0	174,720
1972	25,000	0	0	137	33,264	0	686	52,295	0	0	125,392	2,842	7,275	7,489	0	0	229,380
1973	35,000	0	0	0	2,204	0	0	82,126	0	0	105,777		13,089	0	0	0	203,196
1974	70,000	0	0	431	23,817	0	0	42,053	2,175	0	51,264		2,174	3,078	0	0	124,992
1975	70,000	0	587	0	95,530	0	0	146,534	0	0	137,063	3,614	9,963	7,149	0	0	400,440
1976	100,000	0	1,576	0	7,628	0	0	111,415	839	0	143,981	8,701	6,052	1,171	116	0	281,479
1977	65,000	0	0	0	96,260	0	0	152,290	3,400	0	208,444	231	14,837	0	74	0	475,536
1978	130,000	0	1,738	0	27,569	0	0	46,773	402	0	56,434		22,029	0	0	73	155,018
1979	95,000	0	3,137	0	49,377	0	0	70,843	0	0	87,467		8,654	454	0	0	219,932
1980	141,000	0	205	0	11,241	0	0	48,427	0	0	59,449	290	4,149	0	0	0	123,760
1981	150,000	0	967	0	33,684	37	0	45,923	145	0	82,252	0	7,492	509	0	0	171,010
1982	147,000	0	1,494	0	2,486	0	0	38,490	174	0	32,237	224	5,849	0	0	0	80,954
1983	161,730	0	77	0	12,320	0	317	19,887	0	0	51,467	0	1,389	0	0	0	85,458
1984	80,940	0	174	0	16,772	0	0	27,073	0	0	27,812	0	1,814	181	0	0	73,826
1985	115,720	0	3,012	0	17,797	0	0	32,570	0	0	44,474	0	2,069	134	0	0	100,056
1986	33,854	0	37	0	23,962	0	0	50,682	0	0	45,265	268	1,883	111	0	0	122,208
1987	75,891	0	497	0	35,777	0	0	54,006	86	0	67,881	0	4,954	90	0	0	163,292
1988	50,946	0	701	31	35,795	0	0	61,412	0	0	105,130	0	2,074	179	0	0	205,323
1989	72,601	134	2,213	0	41,446	0	0	84,987	0	0	85,188	0	3,771	138	0	0	217,876
1990	55,931	0	556	0	32,125	0	0	34,731	0	0	26,640	0	611	0	0	0	94,662
1991	94,733	0	1,413	213	52,358	0	0	73,593	0	0	58,708	0	3,896	0	0	0	190,182
1992	74,094	0	869	138	26,244	0	0	52,044	0	0	89,432	0	683	0	0	0	169,408
1993	86,706	0	1,802	0	51,538	0	0	128,688	91	0	40,891	41	2,121	0	0	0	225,172
1994	83,103	0	1,110	0	20,082	0	0	24,841	0	0	32,379	0	2,947	0	0	0	81,359
1995	77,018	0	1,013	0	12,937	0	0	23,326	0	0	49,775	152	2,835	0	0	0	90,038
1996	42,228	0	499	0	17,105	0	0	32,281	0	0	52,228	0	2,618	0	0	0	104,731
1997	82,000	0	284	36	27,205	0	0	45,579	0								
1998	108,037	0	502	0	34,934	0											
1999	54,703	0	707														
2000	47,674																
2001	83,571																
2002	79,141																

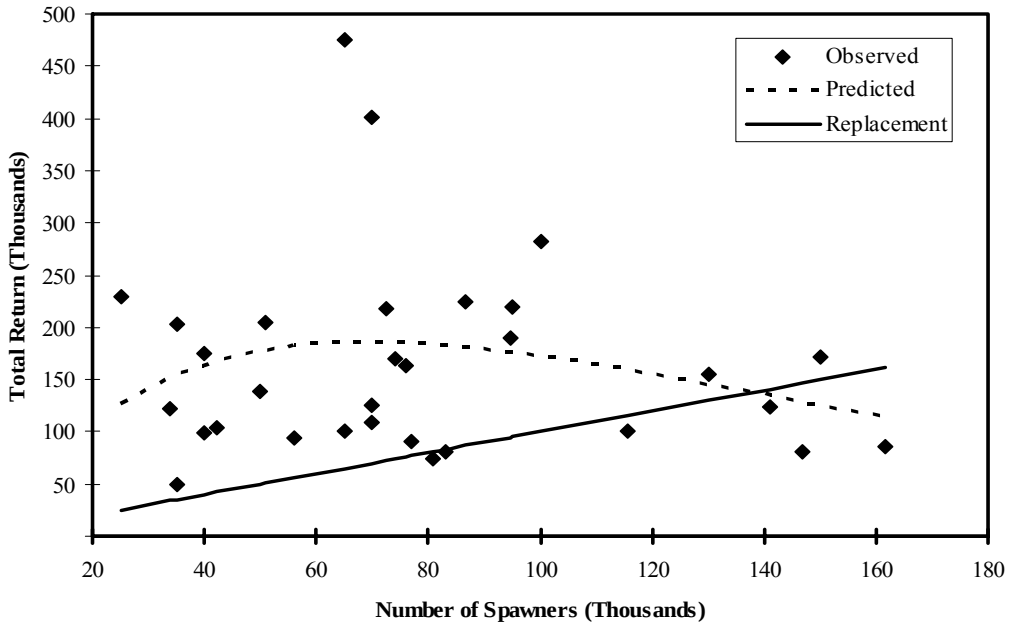
Appendix A1. – Continued.

System: **Nushagak River**
Species: **chinook salmon**

ACF and PACF plots for Ricker stock-recruitment residuals, 1966-1996 brood years.



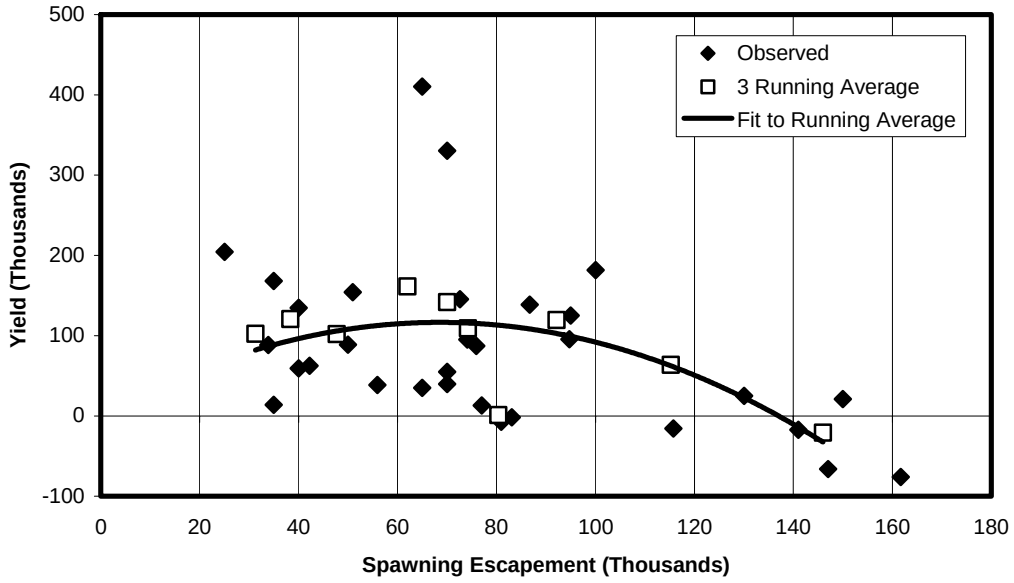
Ricker stock-recruitment relationship, 1966-1996 brood years.



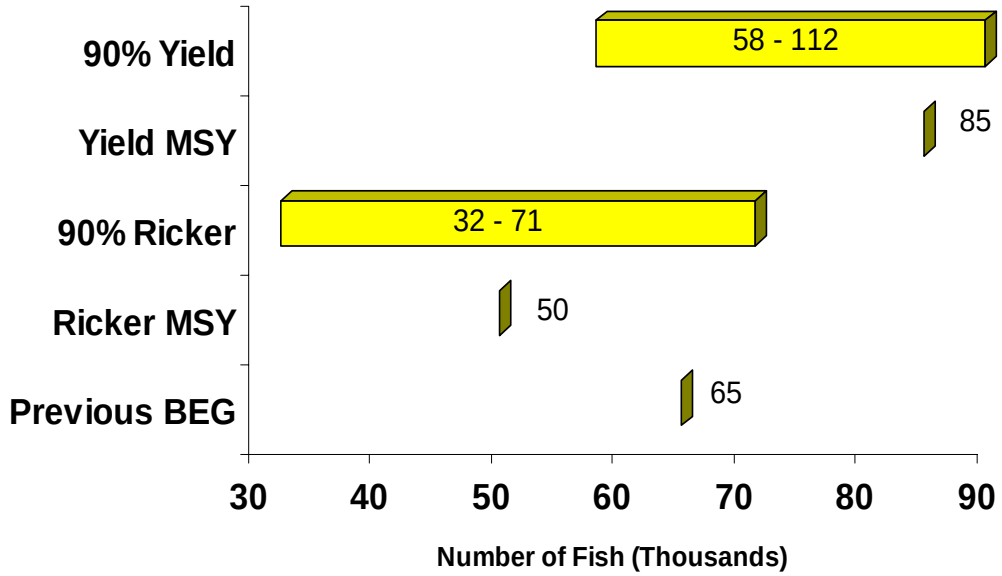
Appendix A1. – Continued.

System: **Nushagak River**
Species: **chinook salmon**

Stock-yield relationship, 1966-1996 brood years.



Summary of current escapement goal and estimates of S_{MSY}.



Appendix A2. – Escapement goal for Alagnak River chinook salmon.

System: Alagnak River
Species: chinook salmon

Description of stock and escapement goals.

Management Division:	Sport Fisheries
Previous Escapement Goal:	None
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	2,700 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Aerial survey counts since 1970
Summary:	
Data Quality	Fair
Data Type	Aerial survey; limited age data
Methodology	Risk analysis
Autocorrelation	Significant autoregressive at lag-1
Years within recommended goal	23 out of 33
Comments	This stock has SEG quality data, and is passively managed and coincidentally harvested. Therefore, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

Appendix A2. – Continued.

System: Alagnak River
Species: chinook salmon

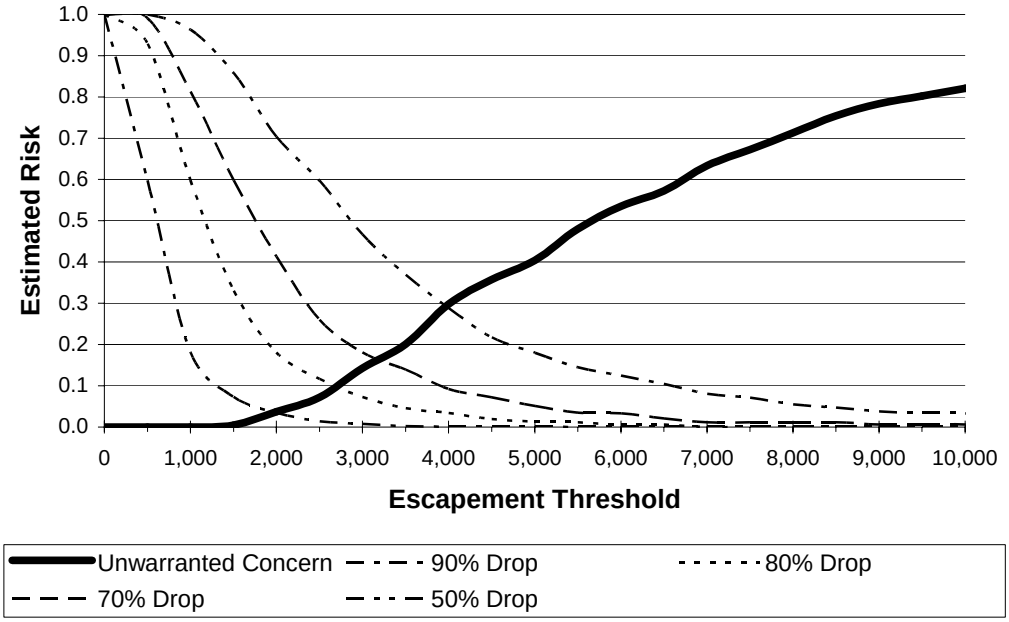
Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)
1970	5,250	8.57
1971	1,475	7.30
1972	2,256	7.72
1973	824	6.71
1974	1,596	7.38
1975	6,620	8.80
1976	7,593	8.93
1977	9,425	9.15
1978	11,650	9.36
1978		
1979	2,930	7.98
1980	2,430	7.80
1981	3,400	8.13
1982	2,980	8.00
1983	6,090	8.71
1984	3,920	8.27
1985	3,090	8.04
1986	2,420	7.79
1987	4,600	8.43
1988	3,650	8.20
1989	1,720	7.45
1990	2,531	7.84
1991	3,042	8.02
1992	10,170	9.23
1993	8,480	9.05
1994	6,860	8.83
1995	9,885	9.20
1996	15,210	9.63
1997	4,148	8.33
1998	2,178	7.69
1999	2,220	7.71
2000	5,458	8.60
2001	3,675	8.21
2002	6,620	8.80
Mean	4,982	8.30
St. dev.	3,384	0.68
Median	3,675	8.21

Appendix A2. – Continued.

System: **Alagnak River**
Species: **chinook salmon**

Risk analysis summary showing the risk of an unwarranted concern and the estimated risk that a drop in various levels of mean escapement would not be detected.



Appendix A3. – Escapement goal for Egegik River chinook salmon.

System: Egegik River
Species: chinook salmon

Description of stock and escapement goals.

Management Division:	Sport Fisheries
Previous Escapement Goal:	None
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	450 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Combined aerial survey counts for Gertrude, Kaye's and Takayoto Creeks since 1985
Summary:	
Data Quality	Poor
Data Type	Aerial survey; no age data
Methodology	Risk analysis
Autocorrelation	No significant autocorrelation
Years within recommended goal	11 out of 15
Comments	This stock has SEG quality data, and is passively managed and coincidentally harvested. Therefore, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

Appendix A3. – Continued.

System: **Egegik River**
Species: **chinook salmon**

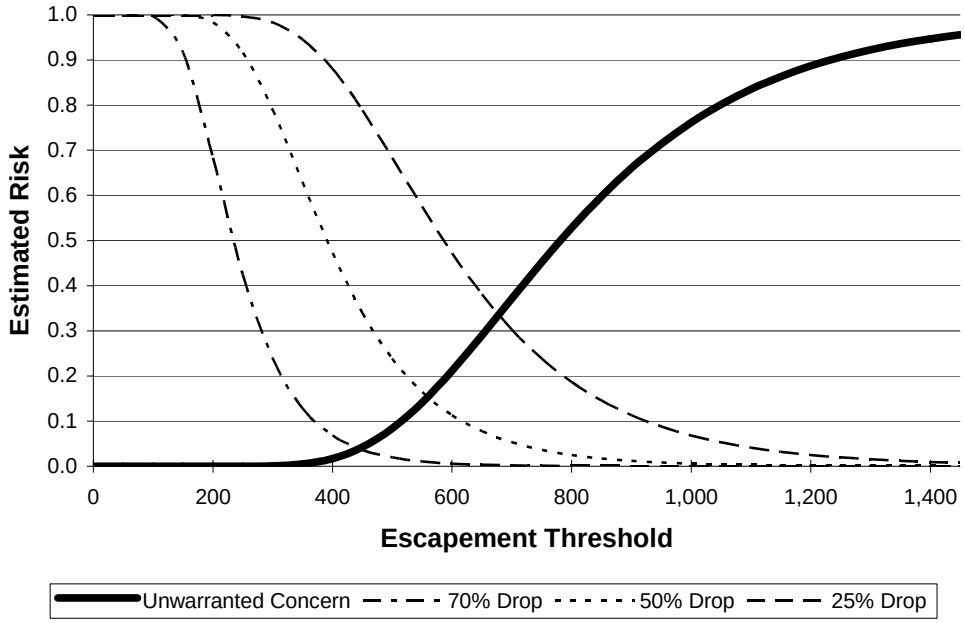
Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)
1985	805	6.69
1986	924	6.83
1987	545	6.30
1988	730	6.59
1989	610	6.41
1990	295	5.69
1991		
1992	720	6.58
1993		
1994		
1995	427	6.06
1996	807	6.69
1997	605	6.41
1998	286	5.66
1999	199	5.29
2000	389	5.96
2001	644	6.47
2002	790	6.67
Mean	585	6.29
St. dev.	221	0.46
Median	610	6.41

Appendix A3. – Continued.

System: **Egegik River**
Species: **chinook salmon**

Risk analysis summary showing the risk of an unwarranted concern and the estimated risk that a drop in various levels of mean escapement would not be detected.



Appendix A4. – Escapement goal for Naknek River chinook salmon.

System: Naknek River
Species: chinook salmon

Description of stock and escapement goals.

Management Division:	Sport Fisheries
Previous Escapement Goal:	5,000 (1994)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	5,000 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Aerial survey counts since 1971
Summary:	
Data Quality	Fair
Data Type	Aerial survey and Big Creek weir; limited age data
Methodology	Risk analysis
Autocorrelation	No significant autocorrelation
Years within recommended goal	12 out of 25
Comments	This stock has SEG quality data, and is passively managed and coincidentally harvested. Therefore, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

Appendix A4. – Continued.

System: Naknek River
Species: chinook salmon

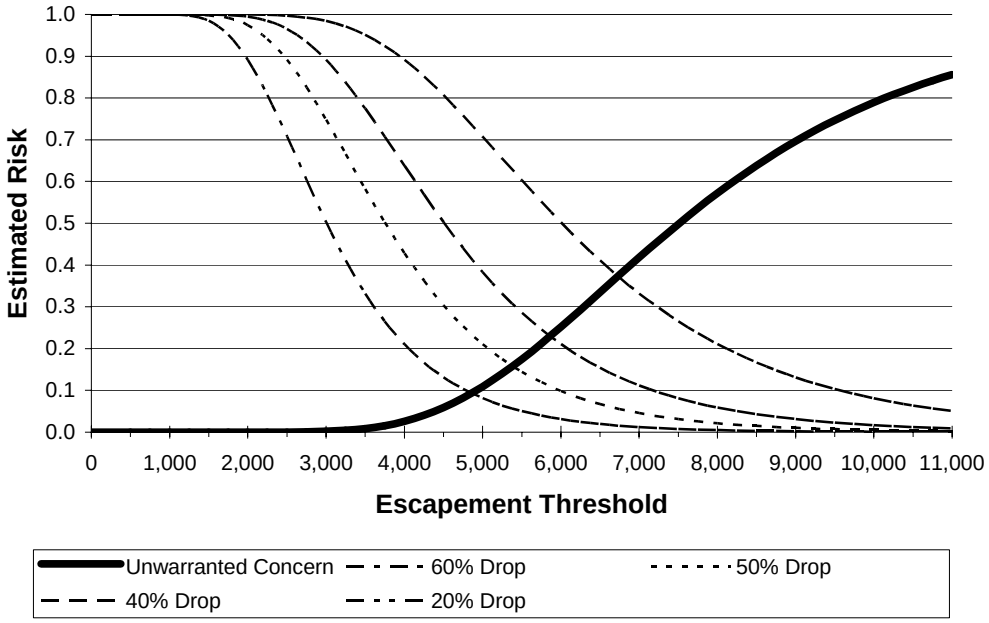
Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)
1971	2,885	7.97
1972	2,791	7.93
1973	2,536	7.84
1974		
1975	3,452	8.15
1976	7,131	8.87
1977		
1978		
1978		
1979		
1980	4,271	8.36
1981	8,610	9.06
1982	7,830	8.97
1983	4,995	8.52
1984		
1985	3,917	8.27
1986	4,450	8.40
1987	11,730	9.37
1988	2,710	7.90
1989	7,000	8.85
1990	4,391	8.39
1991	2,691	7.90
1992	8,016	8.99
1993	9,678	9.18
1994	4,960	8.51
1995	5,010	8.52
1996	10,453	9.25
1997	5,505	8.61
1998		
1999	3,233	8.08
2000	6,340	8.75
2001	7,593	8.93
2002	2,885	7.97
Mean	5,579	8.52
St. dev.	2,638	0.47
Median	4,978	8.51

Appendix A4. – Continued.

System: **Naknek River**
Species: **chinook salmon**

Risk analysis summary showing the risk of an unwarranted concern and the estimated risk that a drop in various levels of mean escapement would not be detected.



Appendix A5. – Escapement goal for Togiak River chinook salmon.

System: Togiak River
Species: chinook salmon

Description of stock and escapement goals.

Management Division:	Sport Fisheries
Previous Escapement Goal:	10,000 (1991)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	9,300 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Expanded aerial survey counts since 1980
Summary:	
Data Quality	Fair
Data Type	Aerial survey; harvest data; limited age data
Methodology	Risk analysis
Autocorrelation	Significant autoregressive at lag-1
Years within recommended goal	12 out of 19
Comments	This stock has SEG quality data, and is passively managed and coincidentally harvested. Therefore, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

Appendix A5. – Continued.

System: Togiak River
Species: chinook salmon

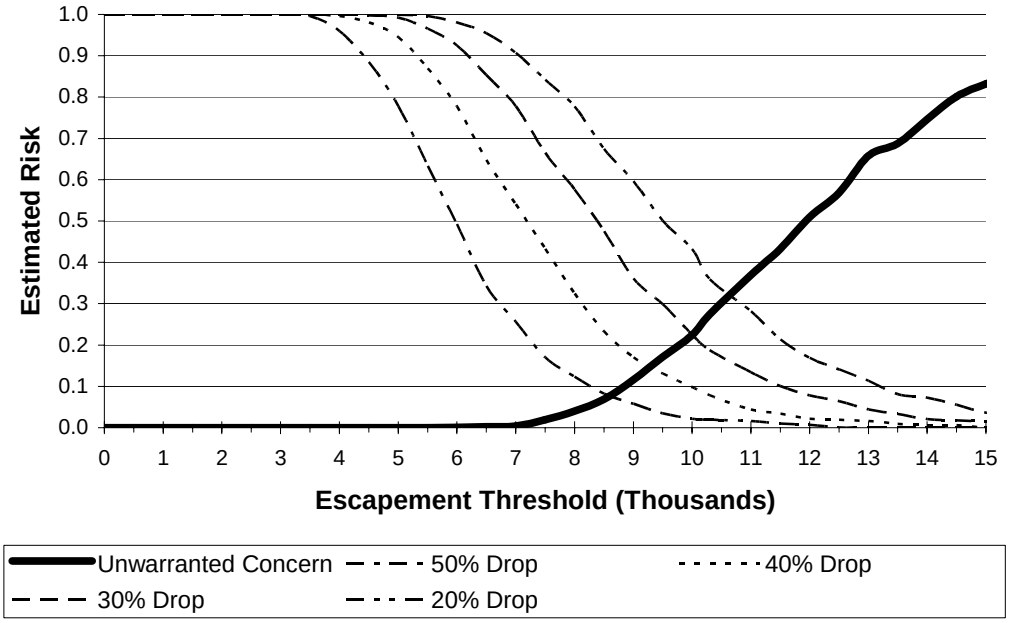
Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)	Commercial Harvest	Subsistence Harvest	Sport Harvest
1980	8,045	8.99	10,858	900	34
1981	12,435	9.43	22,744	400	0
1982	6,800	8.82	33,607	400	231
1983	10,975	9.30	35,669	700	535
1984	19,085	9.86	19,958	600	46
1985	12,010	9.39	33,110	600	925
1986			16,267	700	618
1987	7,170	8.88	14,555	700	338
1988	6,390	8.76	13,205	429	0
1989	6,640	8.80	9,049	551	234
1990	6,475	8.78	9,651	480	445
1991	8,380	9.03	6,472	470	284
1992	7,410	8.91	11,764	1,361	271
1993	10,210	9.23	10,769	749	225
1994	15,115	9.62	9,492	904	663
1995	12,600	9.44	10,736	448	581
1996	8,299	9.02	8,281	471	790
1997	10,300	9.24	5,381	667	1,165
1998	9,856	9.20	12,878	782	763
1999	9,520	9.16	10,668	1,244	644
2000	11,813	9.38	7,254	1,116	470
2001	13,110	9.48	9,518	1,612	600
2002	9,515	9.16	2,654	1,084	600
Mean	10,098	9.18	14,110	755	455
St. dev.	3,168	0.30	9,063	332	308
Median	9,688	9.18	10,769	700	470

Appendix A5. – Continued.

System: **Togiak River**
Species: **chinook salmon**

Risk analysis summary showing the risk of an unwarranted concern and the estimated risk that a drop in various levels of mean escapement would not be detected.



APPENDIX B.
SUPPORTING INFORMATION FOR SOCKEYE SALMON ESCAPEMENT GOALS OF BRISTOL BAY

Appendix B1. – Escapement goal for Egegik River sockeye salmon.

System: Egegik River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	800,000 – 1,400,000 (1997)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	800,000 – 2,000,000
Escapement Goal Type:	BEG
Escapement Estimation:	Tower counts from 1956 to present; smolt data from 1983-2001; 42 years of complete return data available
Summary:	
Data Quality	Excellent
Data Type	Tower counts; commercial harvest; smolt data; age data
Methodology	Ricker stock-recruitment, yield analysis
Autocorrelation	Significant autoregressive correlation at lag-1; smolt data had significant autoregressive correlation at lag-2
Years within recommended goal	28 out of 42
Comments	The analysis was conducted using years for which complete return data were available. The Ricker stock-recruitment relationship has no significant density dependence so we used a Bayesian model with a beta constraining prior. The Bayesian Ricker model and a significant Ricker stock-smolt model provided support for raising the upper end of the goal. The goal represents an estimate of total spawner abundance.

Appendix B1. – Continued.

System: Egegik River
Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1956	1,104	0	6	0	2,025	0	0	3,190	925	0	2	685	1	0	12	0	6,846
1957	391	0	0	0	37	0	0	43	1,096	0	0	927	70	0	62	0	2,235
1958	246	0	0	0	42	2	0	73	817	0	0	308	16	0	3	0	1,261
1959	1,072	0	0	0	73	2	0	164	1,037	0	0	467	14	0	24	0	1,781
1960	1,799	8	0	0	447	21	0	328	4,447	0	1	2,560	49	0	50	0	7,911
1961	702	0	0	3	82	0	0	229	446	0	1	791	28	0	10	0	1,590
1962	1,027	0	0	0	22	0	0	69	950	0	0	375	28	0	30	0	1,474
1963	998	0	0	1	16	2	0	112	538	1	1	506	74	0	7	0	1,258
1964	850	0	1	0	126	6	0	69	1,454	1	0	242	73	0	12	0	1,984
1965	1,445	0	0	0	104	35	0	72	2,016	0	4	845	6	2	20	0	3,104
1966	804	0	0	1	249	0	0	752	600	0	2	890	7	0	10	0	2,511
1967	637	0	0	2	60	2	0	257	665	0	0	622	1	1	2	0	1,612
1968	339	0	0	0	41	0	0	56	87	0	0	258	3	5	9	0	459
1969	1,016	0	0	0	12	1	0	111	1,096	0	0	1,141	279	2	113	0	2,755
1970	920	0	0	0	59	0	0	89	796	0	1	175	95	0	25	0	1,240
1971	634	0	0	0	45	2	0	109	1,477	0	0	970	74	1	55	0	2,733
1972	546	0	0	1	57	2	0	61	1,508	0	0	1,264	48	0	18	0	2,959
1973	329	0	0	0	76	0	0	135	578	0	0	851	35	0	4	0	1,679
1974	1,276	0	0	0	131	18	0	99	2,224	0	0	496	54	0	3	0	3,025
1975	1,174	0	0	0	148	9	0	241	2,449	2	0	797	14	2	1	0	3,663
1976	509	1	1	2	612	59	0	789	3,003	0	4	846	0	0	0	0	5,317
1977	693	0	2	0	823	1	0	1,969	688	0	14	655	52	0	13	0	4,217
1978	896	0	0	2	398	6	0	510	6,071	0	0	2,184	25	4	8	0	9,208
1979	1,032	0	3	0	712	9	3	520	3,036	0	4	1,659	0	0	0	0	5,946
1980	1,061	0	1	13	803	26	0	2,225	4,576	0	6	917	7	0	0	0	8,574
1981	695	0	0	6	544	64	0	953	3,284	0	11	1,438	9	0	7	0	6,316
1982	1,035	2	2	4	988	12	0	1,874	1,796	0	9	1,638	11	2	2	0	6,340
1983	792	0	3	0	1,748	7	1	2,763	3,235	0	7	2,822	21	23	16	0	10,646
1984	1,165	0	1	8	608	85	0	978	6,539	3	10	5,029	215	13	39	0	13,528
1985	1,095	4	0	9	567	32	0	1,404	4,358	0	9	1,262	8	0	18	0	7,671
1986	1,152	0	2	14	1,850	10	0	3,733	3,912	0	92	4,515	86	83	34	0	14,331
1987	1,274	2	0	9	886	66	0	4,561	8,863	3	101	11,239	133	31	57	0	25,951
1988	1,599	0	1	0	413	62	0	1,278	11,061	0	4	5,650	261	3	152	0	18,885
1989	1,612	1	0	6	513	34	0	456	6,063	1	6	3,979	170	1	31	0	11,261
1990	2,192	0	0	2	403	66	0	867	9,598	1	3	4,721	21	28	30	0	15,739
1991	2,787	4	1	3	1,397	20	2	3,939	3,113	0	47	2,607	19	2	9	0	11,163
1992	1,946	5	0	32	335	54	3	1,117	4,963	2	4	3,099	53	16	17	0	9,701
1993	1,517	0	2	10	497	31	0	573	880	0	11	992	6	0	1	0	3,002
1994	1,898	1	8	0	368	65	0	982	4,228	0	0	3,079	11	15	9	0	8,766
1995	1,267	0	7	0	3,151	4	0	3,183	1,648	0	16	1,455	10	11	12	0	9,497
1996	1,076	0	1	0	498	5	0	1,791	515	3	39	1,725	28	0	0		4,604
1997	1,104	0	0	457	34	19	0	322	3,568	9	0	2,238	0				6,646
1998	1,111	0	0	0	104	13											
1999	1,728	1	0														
2000	1,032																
2001	969																
2002	1,036																

Appendix B1. – Continued.

System: Egegik River
Species: sockeye salmon

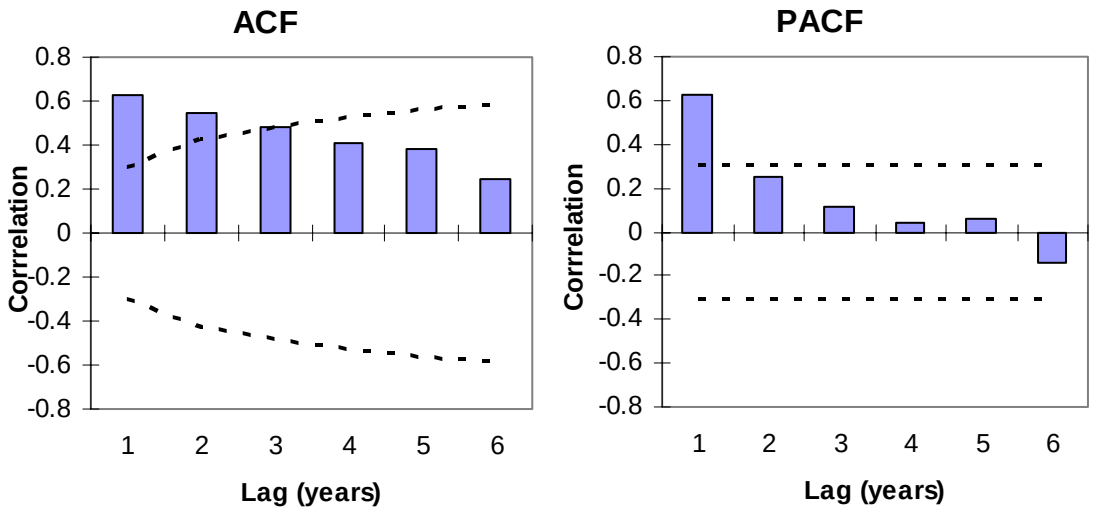
Smolt data available for analysis of escapement goals.

Brood Year	Escapement	Smolt
1980	1,060,920	66,179,555
1981	694,680	34,530,912
1982	1,034,628	28,669,681
1983	792,282	84,655,055
1984	1,165,320	59,483,908
1985	1,095,204	17,236,372
1986	1,151,320	63,469,761
1987	1,272,978	125,153,934
1988	1,599,096	93,318,905
1989	1,610,916	21,895,567
1990	2,191,362	43,787,169
1991	2,786,880	59,373,530
1992	1,945,332	105,939,012
1993	1,516,980	15,704,159
1994	1,897,932	37,863,769
1995	1,265,862	39,894,363
1996	1,076,460	57,897,336
1997	1,104,004	32,590,160
1998	1,110,882	
1999	1,727,772	
2000		

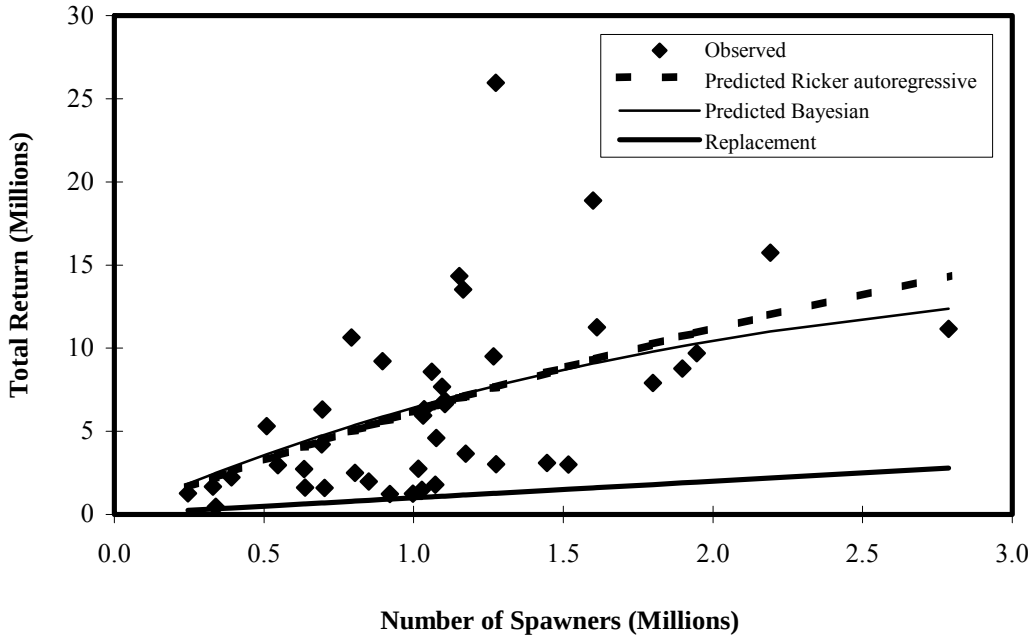
Appendix B1. – Continued.

System: Egegik River
Species: sockeye salmon

ACF and PACF plots for Ricker stock-recruitment residuals, 1956-1997 brood years.



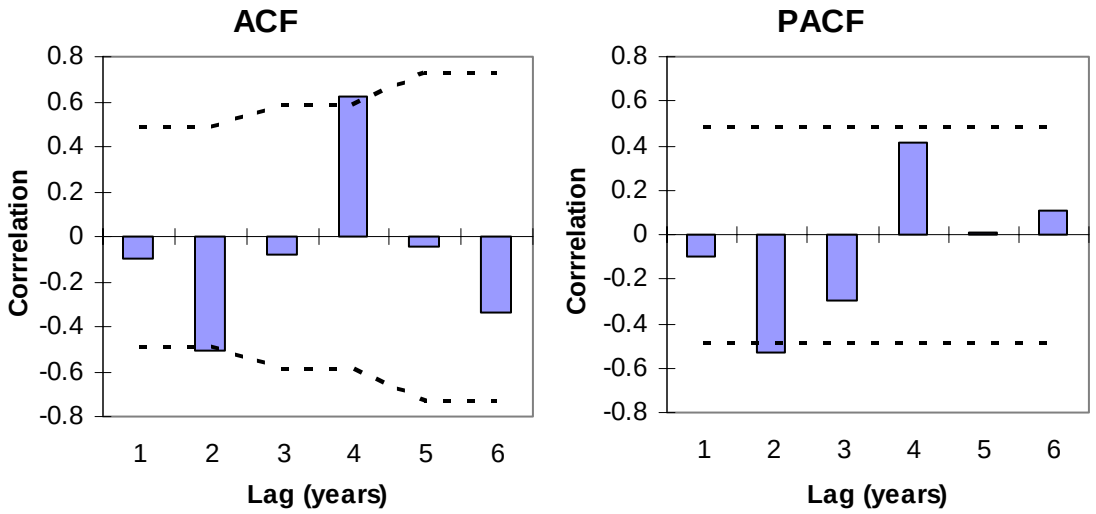
Ricker stock-recruitment relationship, 1956-1997 brood years.



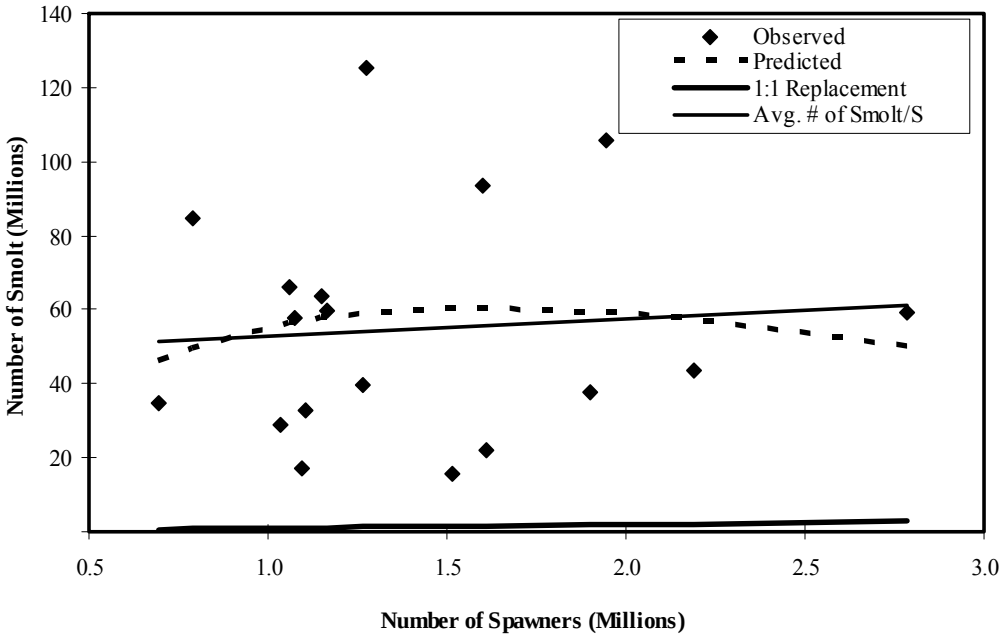
Appendix B1. – Continued.

System: Egegik River
Species: sockeye salmon

ACF and PACF plots for Ricker stock-smolt residuals, 1976-1997 brood years.



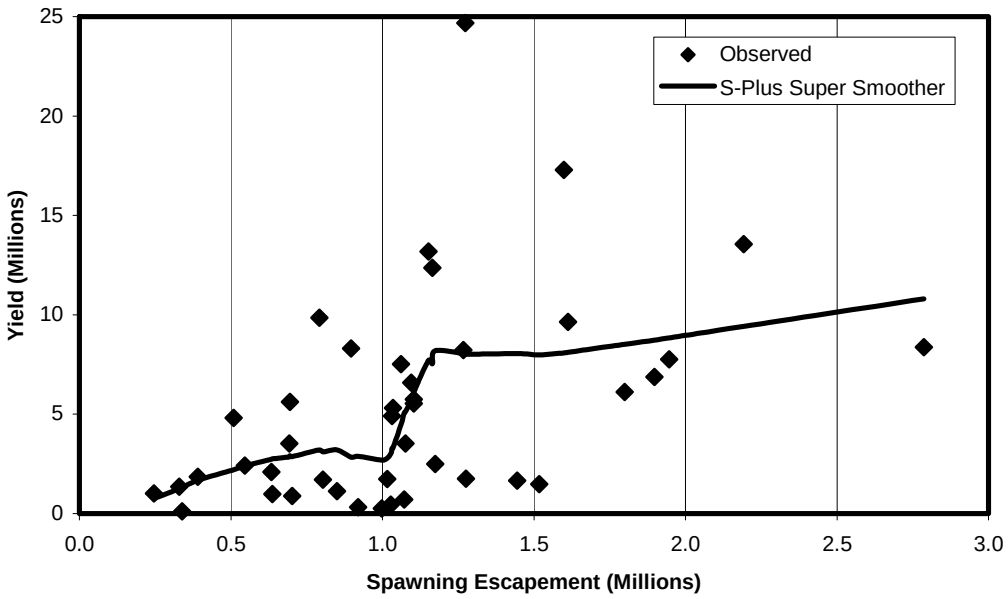
Stock-smolt relationship, 1976-1997 brood years.



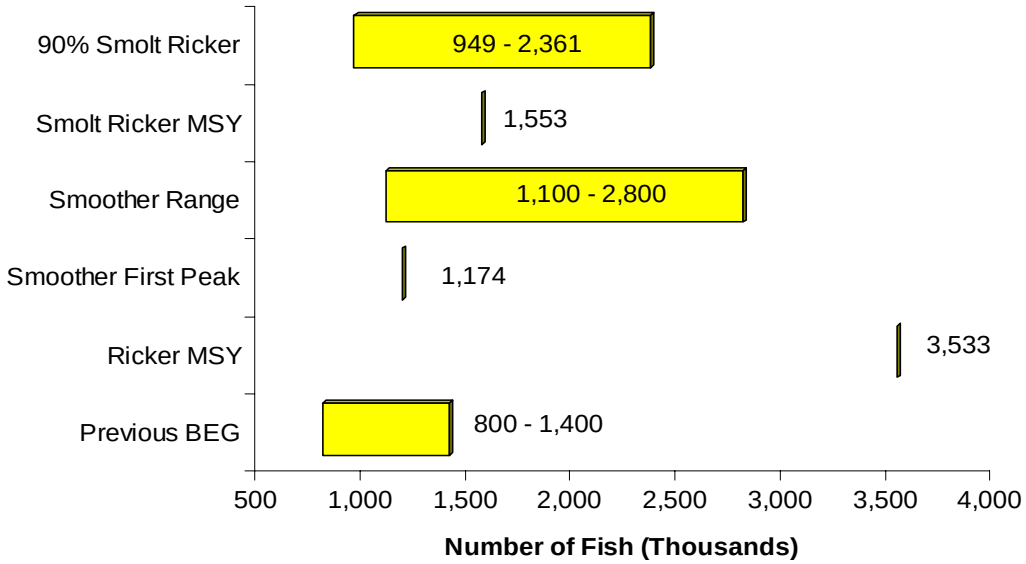
Appendix B1. – Continued.

System: Egegik River
Species: sockeye salmon

Stock-yield relationship, 1956-1997 brood years.



Summary of current escapement goal and estimates of S_{MSY}.



Appendix B2. – Escapement goal for Igushik River sockeye salmon.

System: Igushik River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	150,000 – 300,000 (2000)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	200,000 – 450,000
Escapement Goal Type:	BEG
Escapement Estimation:	Tower counts from 1956 to present; 42 years of complete return data available
Summary:	
Data Quality	Excellent
Data Type	Tower counts; commercial harvest; age data
Methodology	Ricker stock-recruitment (standard brood and Nushagak District aggregate brood), yield analysis
Autocorrelation	Significant autoregressive correlation at lag-1 (all Ricker models)
Years within recommended goal	16 out of 42
Comments	The analysis was conducted using years for which complete return data were available. All standard models and the Nushagak District aggregate model supported raising the lower and upper ranges. The inclusion of the 1980 data point increased the estimates of S_{MSY}. Ricker models were tested with and without 1980, and the yield model did not include 1980. The goal represents an estimate of total spawner abundance.

Appendix B2. – Continued.

System: Igushik River
Species: sockeye salmon

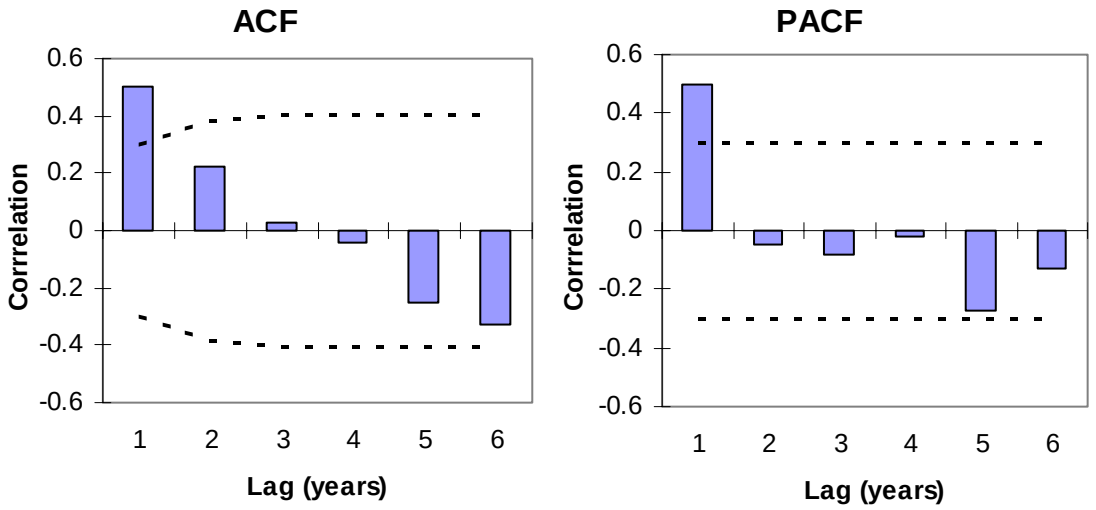
Data available for analysis of escapement goals (in thousands of fish).

Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1956	400	0	0	0	169	0	0	523	12	0	3	36	0	0	0	0	743
1957	130	0	0	0	2	0	0	35	19	0	0	20	0	0	0	0	76
1958	107	0	0	0	14	0	0	71	20	0	0	28	0	0	0	0	133
1959	644	0	0	0	101	0	0	155	93	0	0	22	0	0	0	0	371
1960	495	0	0	1	61	0	0	310	44	0	0	57	0	0	0	0	473
1961	294	0	0	1	33	0	1	364	20	0	0	17	0	0	0	0	436
1962	16	0	0	8	20	0	0	280	9	0	0	9	0	0	0	0	326
1963	92	0	0	3	254	0	0	190	36	0	0	25	0	0	0	0	508
1964	129	0	0	1	162	0	0	585	133	0	0	49	0	0	0	0	930
1965	181	0	0	0	371	0	0	436	203	0	0	80	0	0	0	0	1,090
1966	206	0	0	0	66	0	0	383	6	0	0	15	0	0	0	0	470
1967	282	0	0	3	57	0	0	90	13	0	0	12	0	0	0	0	175
1968	195	0	0	0	43	0	0	120	0	0	2	10	0	0	0	0	175
1969	512	0	0	0	1	0	0	131	301	0	2	103	0	0	0	0	538
1970	371	0	0	1	26	0	0	170	41	0	0	71	0	0	0	0	309
1971	211	0	0	1	48	0	0	164	60	0	0	30	0	0	0	0	303
1972	60	0	0	4	89	0	0	109	6	0	8	13	0	0	0	0	229
1973	60	0	0	0	19	0	0	650	25	0	2	29	0	0	0	0	725
1974	359	0	0	7	441	1	0	750	346	0	4	25	0	0	0	0	1,574
1975	241	0	0	0	783	0	0	2,556	137	0	2	503	0	0	0	0	3,981
1976	186	0	0	0	551	3	0	1,411	194	0	20	215	0	0	0	0	2,394
1977	96	0	0	6	294	0	0	1,689	9	0	8	9	0	0	0	0	2,015
1978	536	0	0	0	96	0	0	330	84	0	1	15	0	0	0	0	526
1979	860	0	0	0	422	0	0	406	13	0	0	5	0	0	0	0	846
1980	1,988	0	0	0	20	0	0	271	25	0	0	56	0	0	0	0	372
1981	591	0	0	0	188	0	0	779	8	0	1	49	0	0	0	0	1,025
1982	424	0	0	7	57	0	0	434	9	0	2	10	0	0	0	0	519
1983	180	1	0	0	151	0	0	353	8	0	2	29	0	0	0	0	544
1984	185	0	0	0	41	0	0	641	56	0	5	36	0	1	0	0	780
1985	212	0	0	7	515	0	0	938	86	0	7	79	0	1	0	0	1,633
1986	308	3	0	14	236	0	1	2,231	27	0	15	30	0	0	0	0	2,557
1987	169	2	0	11	158	0	0	587	7	0	12	29	0	0	0	0	806
1988	170	0	0	1	189	0	1	1,056	41	0	3	36	0	0	0	0	1,327
1989	462	0	0	15	508	0	0	1,119	59	0	7	53	0	0	0	0	1,761
1990	366	1	0	3	159	0	0	1,429	183	0	4	146	0	0	0	0	1,925
1991	756	0	0	1	318	0	0	1,314	3	0	5	20	0	0	0	0	1,661
1992	305	0	0	3	44	0	0	148	8	0	0	26	0	0	0	0	229
1993	406	0	0	1	132	0	2	316	20	0	0	35	0	0	0	0	506
1994	446	0	0	0	238	0	0	846	92	0	1	26	0	0	0	0	1,203
1995	473	0	0	0	653	0	0	1,599	15	0	21	13	0	0	0	0	2,301
1996	401	0	0	0	171	0	0	1,237	1	0	4	4	0	0	0		1,417
1997	128	0	0	19	34	0	0	53	10	0	0	20	0				136
1998	216	0	0	0	144	0											
1999	446	0	0														
2000	413																
2001	410																
2002	123																

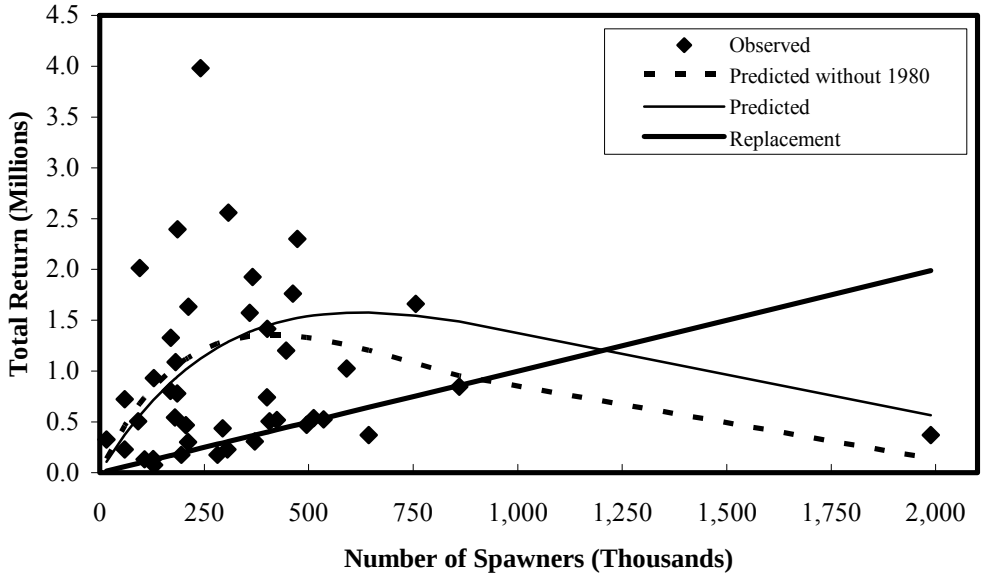
Appendix B2. – Continued.

System: Igushik River
Species: sockeye salmon

ACF and PACF plots for Ricker stock-recruitment residuals, 1956-1997 brood years.



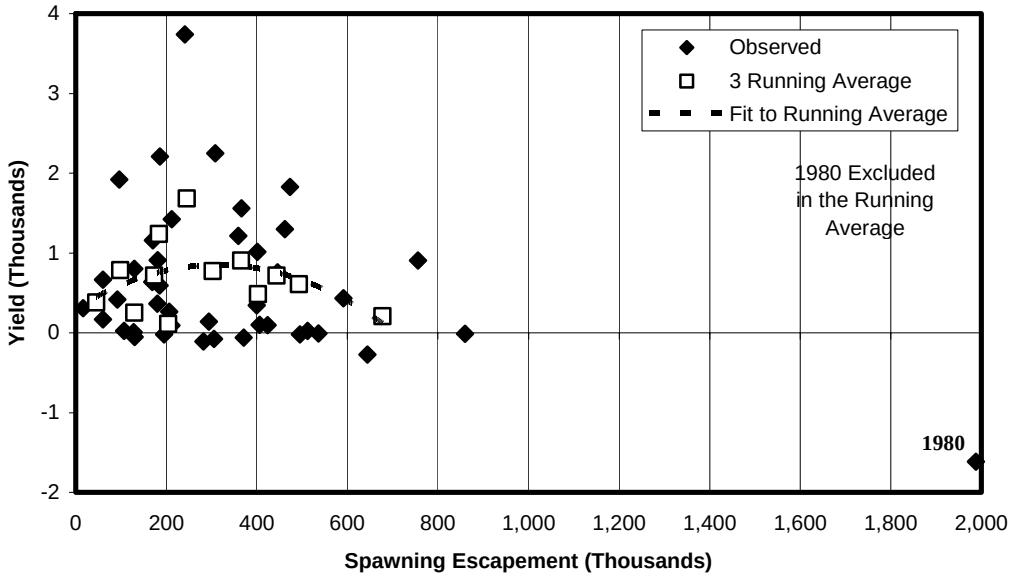
Ricker stock-recruitment relationship, 1956-1997 brood years.



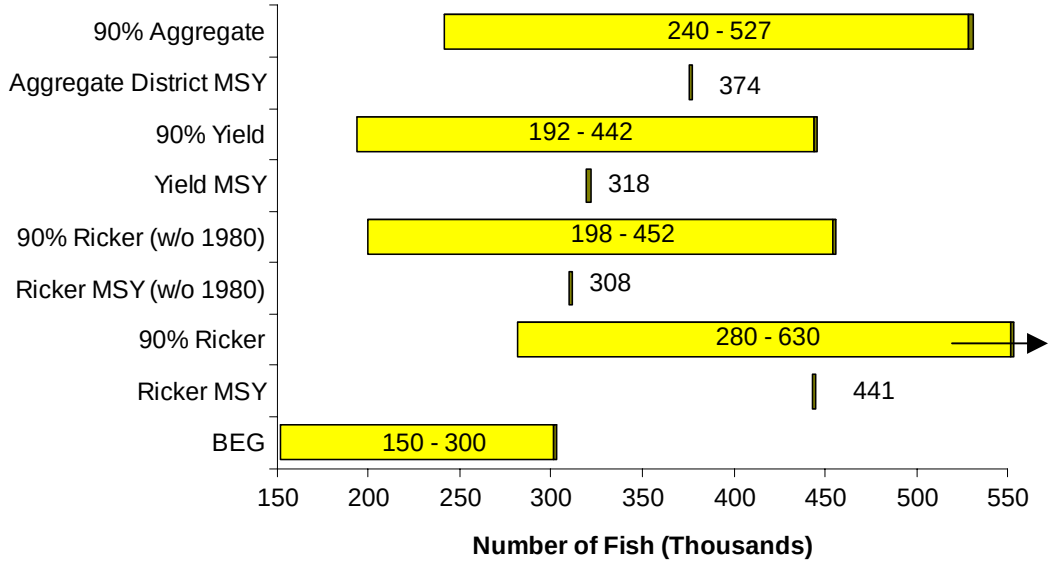
Appendix B2. – Continued.

System: Igushik River
Species: sockeye salmon

Stock-yield relationship, 1956-1997 brood years.



Summary of current escapement goal and estimates of S_{MSY}.



Appendix B3. – Escapement goal for Kvichak River sockeye salmon.

System: Kvichak River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	Off-cycle: 2,000,000 – 10,000,000 (1997) Pre-peak/Peak: 6,000,000 – 10,000,000 (1997)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	Off-cycle: 2,000,000 – 10,000,000 Pre-peak/Peak: 6,000,000 – 17,000,000
Escapement Goal Type:	BEG
Escapement Estimation:	Tower counts from 1956 to present; smolt data from 1971-2000; 42 years of complete return data available
Summary:	
Data Quality	Excellent
Data Type	Tower counts; smolt data; commercial harvest; age data
Methodology	Ricker stock-recruitment, yield analysis
Autocorrelation	Significant autoregressive correlation at lag-1
Years within recommended goal	Off-cycle: 15 out of 26 Pre-peak/Peak: 11 out of 16
Comments	The analyses were conducted using years for which complete return data were available. In addition to the MSY analyses using off-cycle and pre-peak/peak data sets individually, a Ricker 2-stage model incorporated all data into a single autoregressive model. Model results support the existing off-cycle goal. Conversely, there was overwhelming evidence that the pre-peak/peak upper range should be raised. The goal represents an estimate of total spawner abundance.

Appendix B3. – Continued.

System: Kvichak River
Species: sockeye salmon

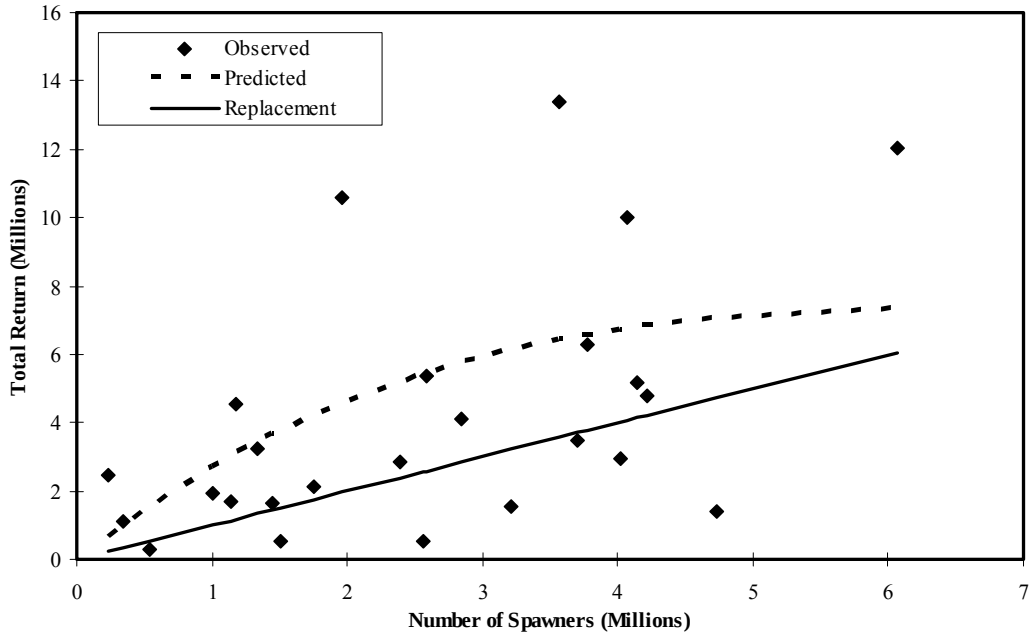
Data available for analysis of escapement goals (in thousands of fish).

Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1956	9,443	0	14	0	24,273	0	0	6,968	6,472	0	0	1,308	0	0	0	0	39,035
1957	2,843	8	0	0	243	0	0	244	3,333	0	2	259	0	0	2	0	4,091
1958	535	0	0	0	76	0	0	48	135	0	0	26	0	0	3	0	288
1959	680	0	0	0	212	1	0	117	206	0	0	11	0	0	0	0	547
1960	14,630	0	0	1	1,314	134	0	563	46,746	0	0	6,485	10	0	6	0	55,259
1961	3,706	1	0	0	334	0	0	190	2,293	0	0	679	5	0	0	0	3,502
1962	2,581	0	0	0	104	2	0	152	4,675	0	0	408	12	0	4	0	5,357
1963	339	0	0	0	49	3	0	50	639	0	0	366	3	0	9	0	1,119
1964	957	0	8	0	2,232	105	0	407	2,341	0	0	647	8	0	3	0	5,751
1965	24,326	0	25	0	9,853	484	0	471	32,951	0	0	1,239	2	0	1	0	45,026
1966	3,775	4	11	6	497	11	0	1,086	4,262	0	0	385	0	1	0	0	6,263
1967	3,216	0	0	5	349	2	0	272	812	0	0	86	0	0	0	0	1,526
1968	2,557	0	0	0	293	0	0	34	77	0	5	132	0	0	2	0	543
1969	8,394	0	0	1	129	7	0	321	4,221	0	0	595	19	0	11	0	5,304
1970	13,935	0	1	0	43	40	0	13	14,463	6	0	848	412	0	7	0	15,833
1971	2,387	0	0	0	244	18	0	93	2,169	0	0	303	2	0	0	0	2,829
1972	1,010	0	0	0	255	1	0	159	1,206	0	22	297	0	0	0	0	1,940
1973	227	0	0	2	576	2	2	1,028	274	0	3	543	28	0	0	0	2,458
1974	4,434	0	9	1	6,328	309	0	2,009	16,725	0	8	763	23	0	5	0	26,180
1975	13,140	0	5	0	5,683	302	0	1,232	30,263	0	0	599	2	0	0	0	38,086
1976	1,965	0	5	11	5,298	43	0	826	4,115	0	4	273	0	0	0	0	10,575
1977	1,341	11	43	6	1,934	2	0	935	208	0	0	99	0	0	0	0	3,238
1978	4,149	0	0	0	1,835	16	0	1,157	1,318	0	0	817	11	0	6	0	5,160
1979	11,218	1	57	3	18,331	73	0	2,234	17,931	0	0	3,512	0	0	0	0	42,142
1980	17,505	0	2	5	2,889	20	0	1,641	8,076	0	2	413	0	0	0	0	13,048
1981	1,754	0	0	12	789	0	0	231	931	0	0	167	0	0	0	0	2,130
1982	1,135	25	0	2	445	1	0	544	524	0	6	139	0	0	0	0	1,686
1983	3,570	0	1	5	8,596	3	0	3,010	1,195	0	5	573	0	2	1	0	13,391
1984	10,491	0	0	4	2,532	44	1	1,924	16,952	0	0	2,483	8	0	2	0	23,950
1985	7,211	4	7	30	1,024	29	0	1,282	13,465	0	2	1,560	1	15	2	0	17,421
1986	1,179	10	0	27	688	0	1	1,079	1,390	0	25	1,332	2	0	4	0	4,558
1987	6,066	29	4	69	4,179	31	4	2,519	4,499	0	5	700	4	0	2	0	12,045
1988	4,065	11	5	19	2,503	19	1	2,470	4,385	0	5	557	11	0	6	0	9,991
1989	8,318	29	2	54	2,147	117	2	1,678	18,826	0	2	3,316	13	1	0	0	26,187
1990	6,970	6	8	11	1,541	83	0	1,192	21,105	0	0	1,162	0	1	0	0	25,109
1991	4,223	0	1	4	2,688	2	0	1,232	699	0	6	170	0	0	0	0	4,802
1992	4,726	2	0	13	429	2	0	226	567	0	0	175	0	0	6	0	1,420
1993	4,025	0	0.9	1	852	1	4	890	624	0	8	574	0	0	0	0	2,955
1994	8,338	0	3	0	1,811	29	0	1,204	3,777	0	1	250	1	0	0	0	7,076
1995	10,039	0	17	0	7736	0	0	1810	600	0	5	76	0	0	0	0	10,244
1996	1,451	4	0	0	369	0	0	1,203	19	0	9	16	0	0	0		1,620
1997	1,504	0	0	4	130	0	1	107	263	0	0	35	0				540
1998	2,296	0	0	2	323	1											
1999	6,197	4	1														
2000	1,828																
2001	1,095																
2002	704																

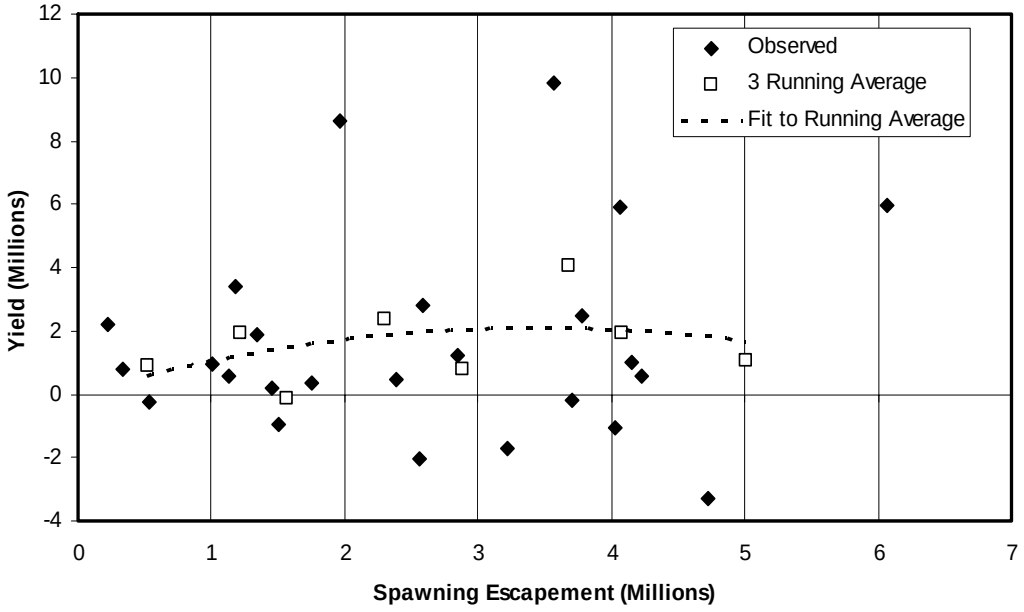
Appendix B3. – Continued.

System: Kvichak River
Species: sockeye salmon

Ricker off-cycle stock-recruitment relationship, 1957-1997 brood years.



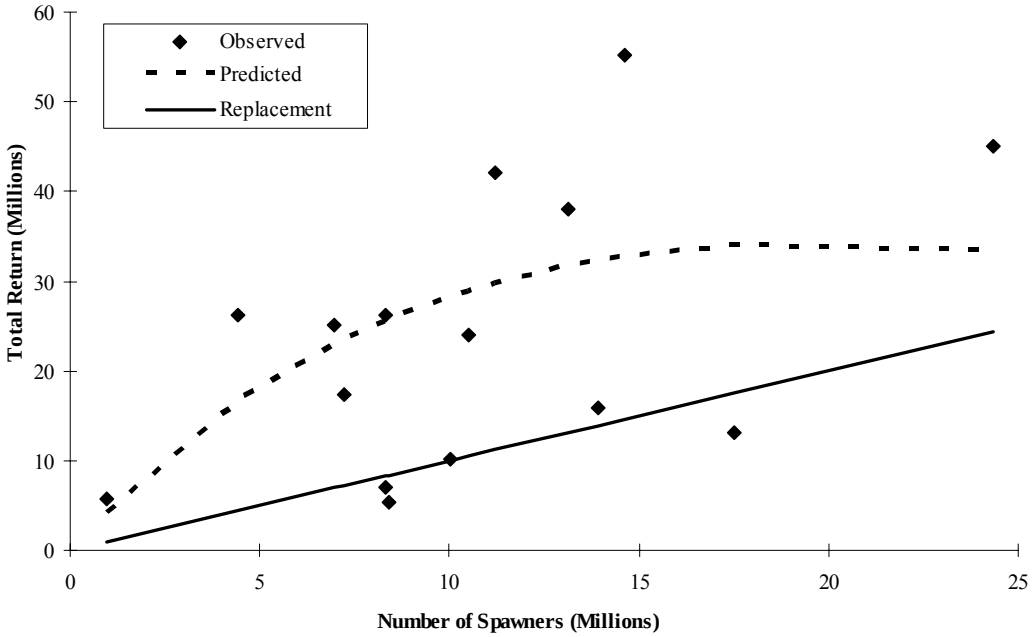
Off-cycle stock-yield relationship, 1956-1997 brood years.



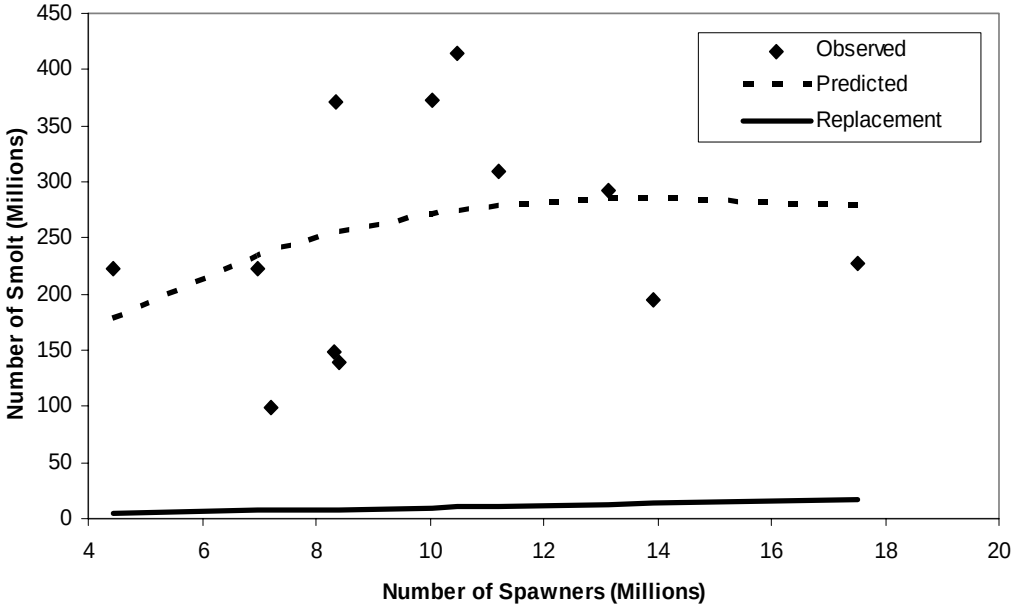
Appendix B3. – Continued.

System: Kvichak River
Species: sockeye salmon

Ricker pre-peak/peak stock-recruitment relationship, 1960-1995 brood years.



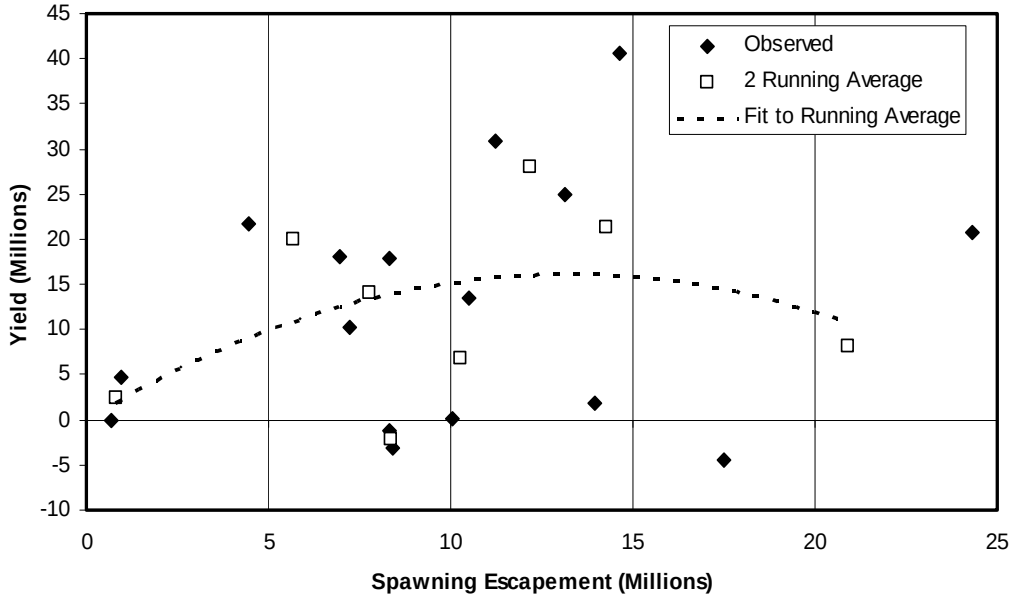
Pre-peak/peak stock-smolt relationship, 1969-1995 brood years.



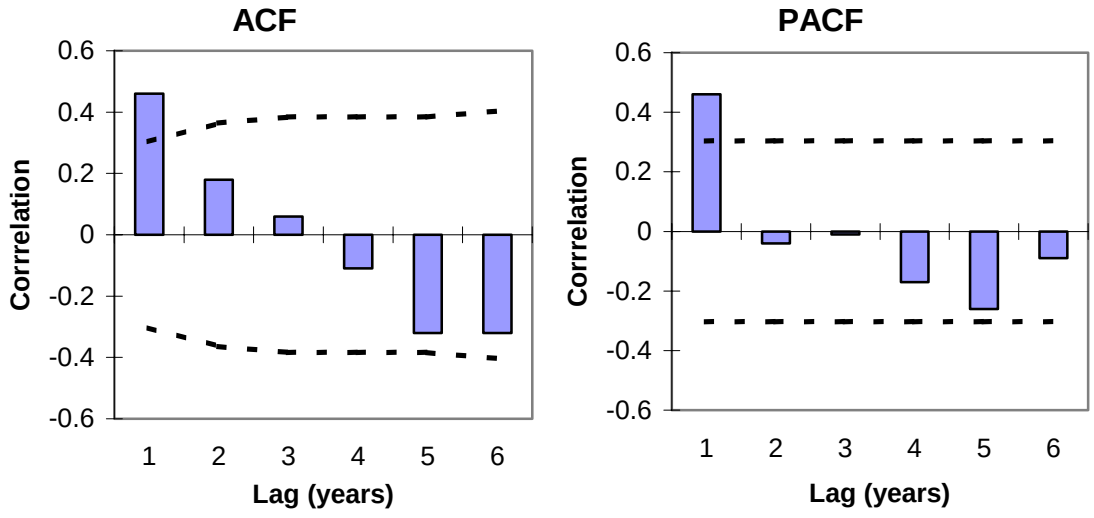
Appendix B3. – Continued.

System: Kvichak River
Species: sockeye salmon

Pre-peak/peak stock-yield relationship, 1959-1995 brood years.



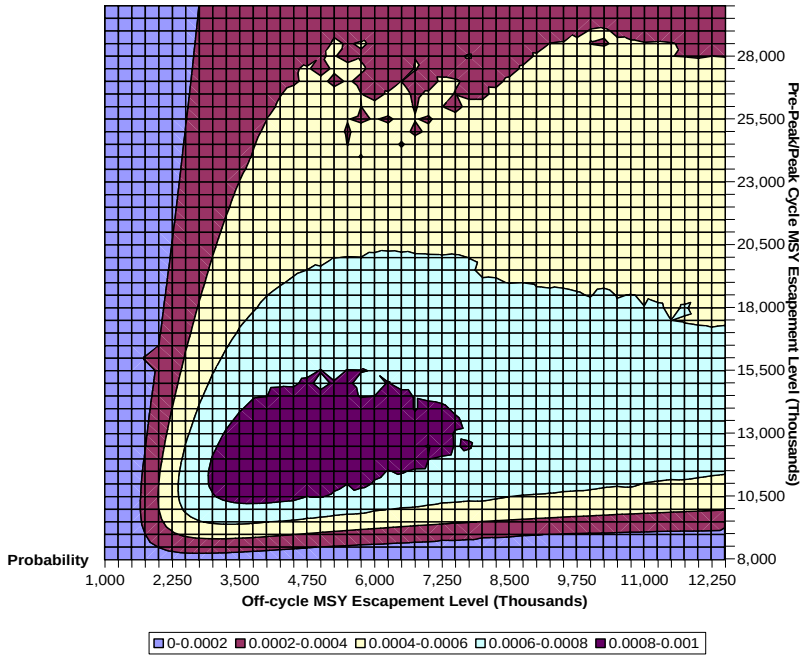
ACF and PACF plots for 2-stage Ricker stock-recruitment residuals, 1956-1997 brood years.



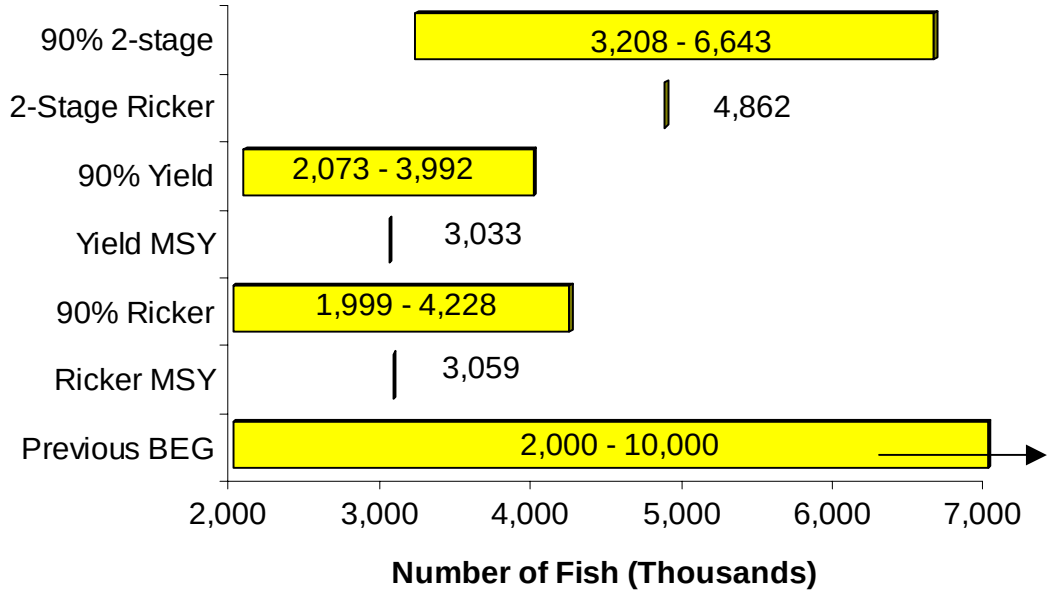
Appendix B3. – Continued.

System: Kvichak River
Species: sockeye salmon

Likelihood profile for Ricker 2-stage autoregressive stock-recruitment model, pre-peak/peak & off-cycle, 1956-1997 brood years.



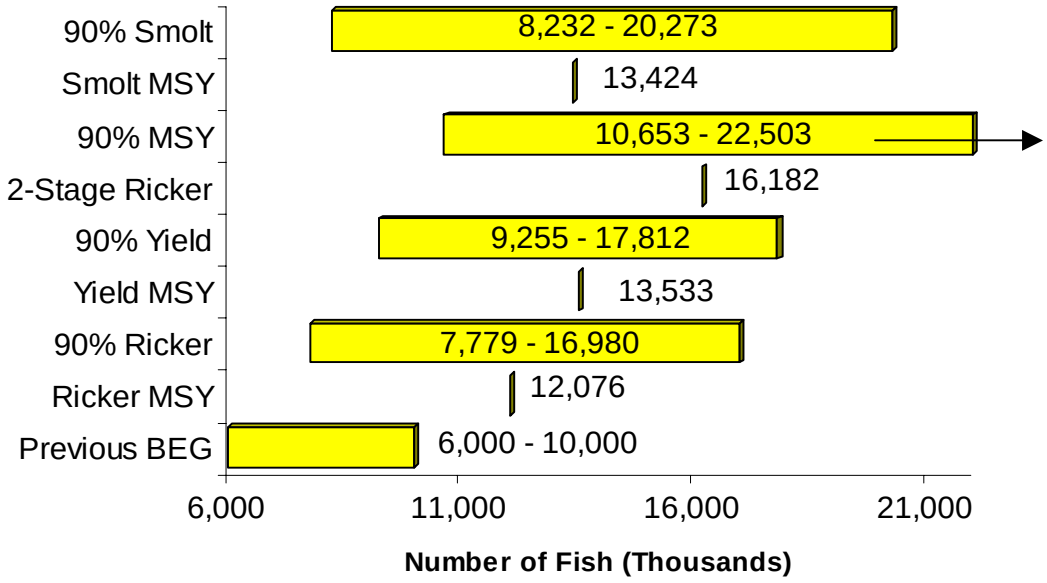
Summary of current off-cycle escapement goal and estimates of S_{MSY}.



Appendix B3. – Continued.

System: Kvichak River
Species: sockeye salmon

Summary of current pre-peak/peak escapement goal and estimates of S_{MSY}.



Appendix B4. – Escapement goal for Naknek River sockeye salmon.

System: Naknek River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	800,000 – 1,400,000 (1984)
Inriver Goal:	None
Optimal Escapement Goal:	2,000,000
Recommended Escapement Goal:	1,000,000 – 2,000,000
Escapement Goal Type:	BEG
Escapement Estimation:	Tower counts from 1956 to present; 42 years of complete return data available
Summary:	
Data Quality	Excellent
Data Type	Tower counts; commercial harvest; age data
Methodology	Ricker stock-recruitment, yield analysis
Autocorrelation	No significant autocorrelation
Years within recommended goal	20 out of 41
Comments	The analyses were conducted using years for which complete return data were available. All MSY models indicated that the lower and upper goals should be raised. The goal represents an estimate of total spawner abundance.

Appendix B4. – Continued.

System: Naknek River
Species: sockeye salmon

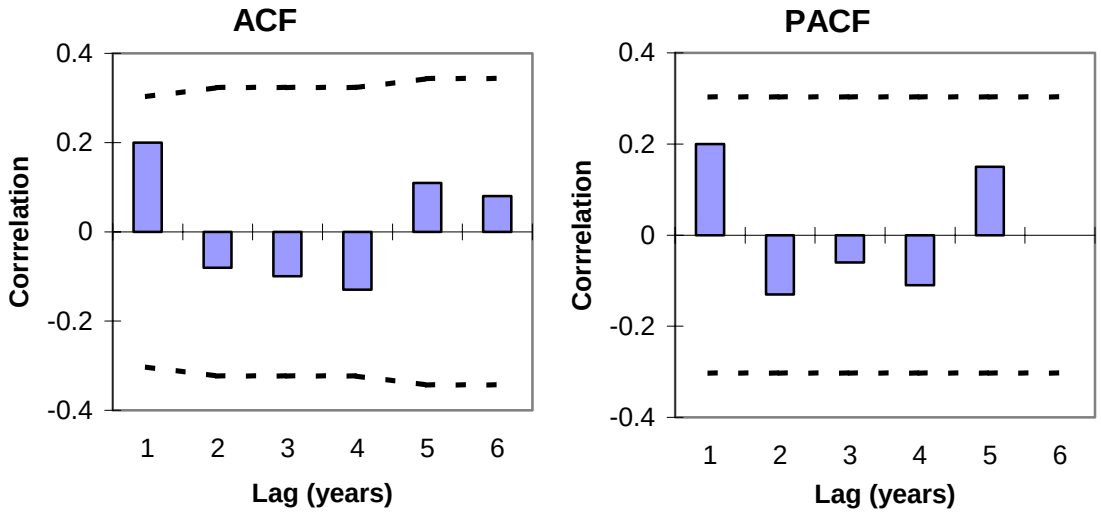
Data available for analysis of escapement goals (in thousands of fish).

Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1956	1,773	0	1	0	473	0	0	1,701	3	0	17	304	0	0	0	0	2,499
1957	635	0	0	0	53	2	0	329	505	0	1	674	5	0	3	0	1,572
1958	278	0	0	0	112	4	0	211	539	0	0	168	3	0	2	0	1,039
1959	2,232	0	0	0	349	7	0	351	742	0	0	705	0	0	0	0	2,154
1960	828	0	1	1	1,408	9	0	625	696	0	0	1,278	1	1	2	0	4,022
1961	351	0	0	0	239	3	0	744	315	0	3	640	0	0	8	0	1,952
1962	723	0	0	0	76	4	0	230	351	0	2	397	13	0	1	0	1,074
1963	905	0	0	0	136	8	0	390	833	0	0	627	7	0	1	0	2,002
1964	1,350	0	1	0	447	24	0	264	1,135	0	0	177	11	0	1	0	2,060
1965	718	0	5	0	540	44	0	360	732	0	0	437	1	0	1	0	2,120
1966	1,016	1	4	0	728	2	0	2,304	167	0	1	630	0	1	0	0	3,838
1967	756	0	0	2	326	6	0	625	401	0	0	356	0	1	0	0	1,717
1968	1,023	0	3	0	152	0	0	234	83	0	0	269	2	0	2	0	745
1969	1,331	0	0	0	47	3	0	307	976	0	0	1,211	5	0	3	0	2,552
1970	733	0	1	0	154	19	0	318	1,845	0	0	370	12	0	0	0	2,719
1971	936	0	1	0	397	24	0	559	1,428	0	0	1,844	3	9	8	0	4,273
1972	587	0	3	0	245	3	0	241	161	0	3	599	9	0	1	0	1,265
1973	357	0	0	0	494	0	0	618	524	0	0	598	0	0	0	0	2,234
1974	1,241	0	2	0	232	3	0	228	1,026	0	1	783	5	0	5	0	2,285
1975	2,027	0	1	0	425	11	0	1,746	1,393	0	0	1,641	1	8	0	0	5,226
1976	1,321	0	4	0	1,084	3	0	4,048	1,575	0	21	1,491	0	28	1	0	8,255
1977	1,086	2	10	7	635	0	0	2,272	95	0	64	401	0	1	5	0	3,492
1978	813	0	1	0	331	4	0	1,695	1,121	0	11	530	2	0	0	0	3,695
1979	925	0	4	1	2,438	4	0	973	792	0	9	408	4	0	3	0	4,636
1980	2,645	0	1	1	723	14	0	1,505	1,192	0	9	828	0	2	0	0	4,275
1981	1,796	0	4	0	782	9	0	2,568	473	0	12	937	0	3	0	0	4,788
1982	1,156	0	3	3	185	0	0	1,172	191	0	23	457	0	9	0	0	2,043
1983	888	0	0	1	163	7	0	484	336	0	5	480	0	0	1	0	1,477
1984	1,242	0	1	0	469	23	0	911	1,214	0	21	1,828	5	1	4	0	4,477
1985	1,850	0	2	6	656	20	1	3,533	1,293	0	44	1,441	0	28	10	0	7,034
1986	1,978	0	3	6	1,981	6	1	7,167	1,276	0	367	2,817	1	38	2	0	13,665
1987	1,062	3	0	12	336	4	1	1,251	565	0	95	3,225	2	12	0	0	5,506
1988	1,038	0	0	0	273	13	0	796	516	0	37	544	2	2	1	0	2,184
1989	1,162	0	1	0	226	5	0	930	1,154	0	0	566	4	0	1	0	2,887
1990	2,093	0	0	0	405	46	0	1,236	1,345	0	12	1,316	3	12	0	0	4,375
1991	3,579	1	13	0	546	1	0	5,209	250	0	45	343	0	1	0	0	6,408
1992	1,607	0	0	16	268	1	0	552	250	1	10	379	5	2	0	0	1,484
1993	1,536	0	0	2	293	12	0	1,390	473	0	23	692	0	0	0	0	2,885
1994	991	0	6	0	503	15	0	631	553	0	7	526	4	7	0	0	2,251
1995	1,111	0	9	0	2,067	1	1	3,896	156	0	65	280	0	5	0	0	6,479
1996	1,078	1	1	0	345	0	0	6,117	83	0	108	353	1	0	0		7,009
1997	1,026	0	0	2	119	9	0	850	819	0	0	1,043	0				2,842
1998	1,202	0	1	0	623	3											
1999	1,625	0	0														
2000	1,375																
2001	1,830																
2002	1,264																

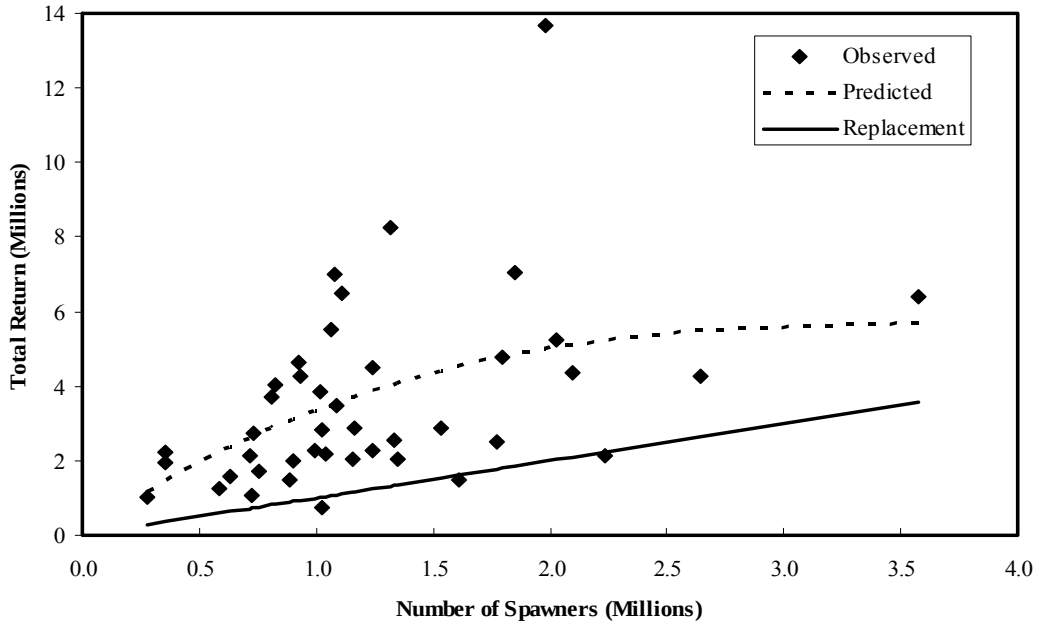
Appendix B4. – Continued.

System: Naknek River
Species: sockeye salmon

ACF and PACF plot for Ricker stock-recruitment residuals, 1956-1997 brood years.



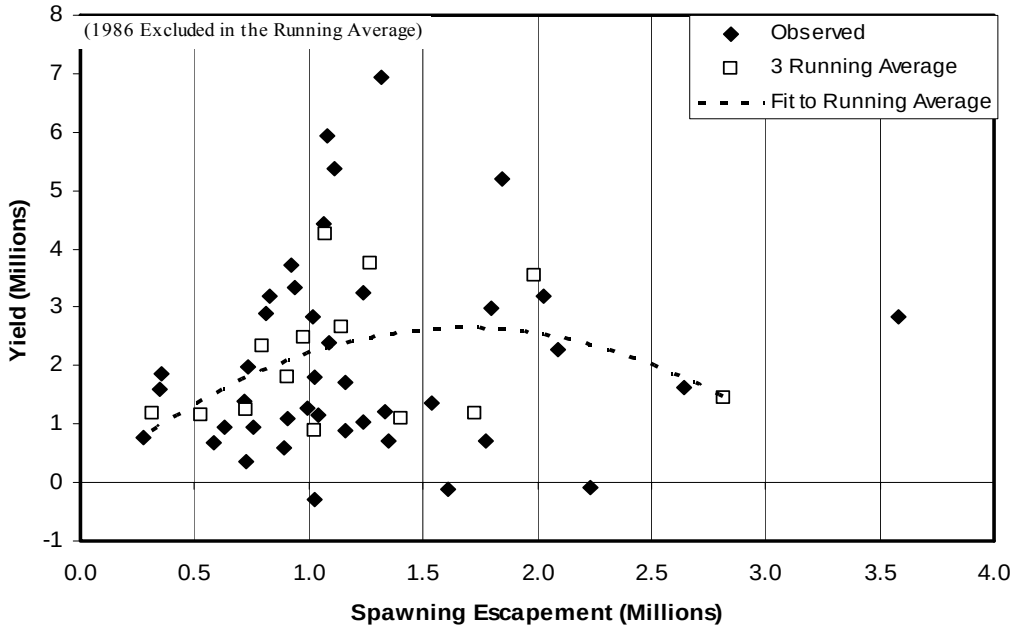
Ricker stock-recruitment relationship, 1956-1997 brood years.



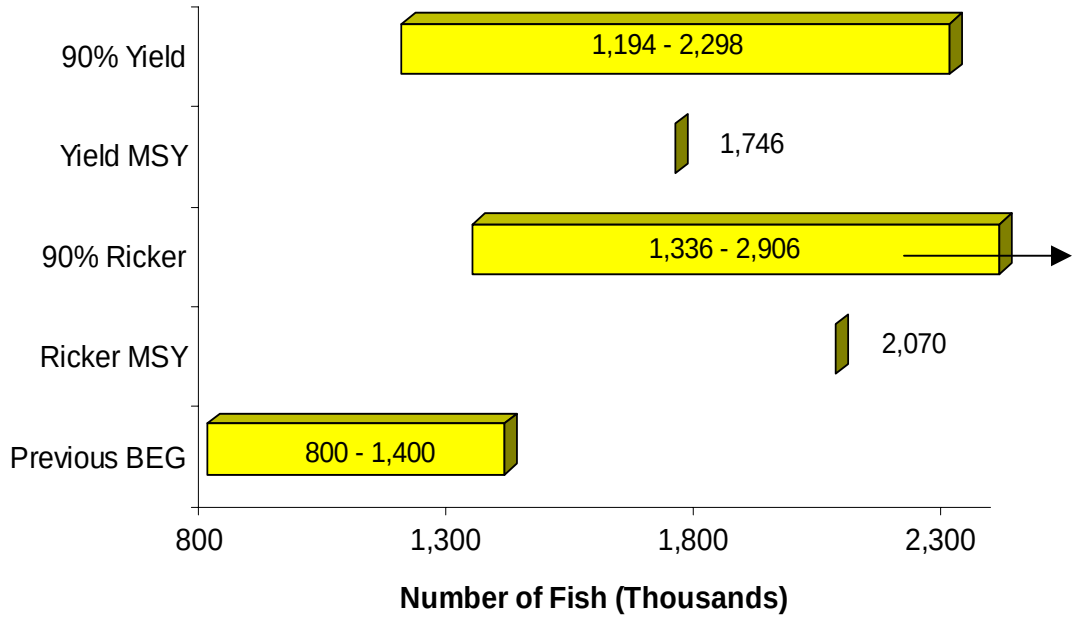
Appendix B4. – Continued.

System: Naknek River
Species: sockeye salmon

Stock-yield relationship, 1956-1997 brood years.



Summary of current escapement goal and estimates of S_{MSY}.



Appendix B5. – Escapement goal for Nushagak River sockeye salmon.

System: Nushagak River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	340,000 – 760,000 (1997)
Inriver Goal:	None
Optimal Escapement Goal:	235,000
Recommended Escapement Goal:	Same
Escapement Goal Type:	BEG
Escapement Estimation:	Nuyakuk tower and expanded aerial survey counts from 1974-1979; sonar counts from 1980 to present; 20 years of complete return data available
Summary:	
Data Quality	Good
Data Type	Tower, aerial survey, and sonar counts; commercial harvest; age data
Methodology	Ricker stock-recruitment (standard brood table and Nushagak District aggregate brood table), yield analysis
Autocorrelation	Significant autoregressive correlation at lag-1 – Aggregate District model only
Years within recommended goal	16 out of 20
Comments	The analyses were conducted using years for which complete return data were available. The standard Ricker and yield models with 1980 suggest raising the goal. However, models excluding 1980, and the Nushagak District aggregate model support the current goal. There was no compelling evidence to change the goal, which represents an estimate of total spawner abundance.

Appendix B5. – Continued.

System: Nushagak River
Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1978	664			436	100	0	149	779	20	0	1	6	0	1	0	0	1,491
1979	499	18	1	466	494	0	16	854	6	0	42	5	0	0	0	0	1,902
1980	3,317	19	0	447	84	0	67	344	162	0	4	156	0	0	0	0	1,284
1981	1,012	9	0	137	170	0	14	1,476	2	0	86	32	0	0	0	0	1,926
1982	601	35	0	351	164	0	49	894	2	0	62	7	0	0	0	0	1,563
1983	404	100	0	608	114	0	122	553	6	0	16	3	0	0	0	0	1,521
1984	593	10	0	226	51	0	32	566	2	0	20	6	0	0	0	0	912
1985	498	68	0	510	64	0	62	612	6	0	13	16	0	1	0	0	1,351
1986	990	68	0	837	114	0	58	676	0	0	182	64	0	0	0	0	1,999
1987	388	140	0	933	36	0	253	535	36	0	101	10	0	1	0	0	2,047
1988	483	68	0	546	214	0	120	1,426	12	0	62	8	0	0	0	0	2,457
1989	513	68	0	483	124	0	35	703	1	0	18	4	0	0	0	0	1,436
1990	680	53	0	761	36	0	104	253	18	0	11	7	0	4	0	0	1,247
1991	493	10	1	137	172	0	6	1,010	3	0	131	19	0	0	0	0	1,491
1992	695	85	0	496	228	0	11	650	9	0	63	11	0	0	0	0	1,551
1993	715	43	0	43	63	0	2	803	1	0	119	49	0	0	0	0	1,124
1994	509	0	0	55	81	0	2	665	6	0	9	53	0	0	0	0	872
1995	281	5	1	8	143	0	0	923	34	0	109	15	0	0	0	0	1,239
1996	504	0	0	6	502	0	5	1,795	3	0	58	5	0	0	0		2,374
1997	373	0	0	129	71	0	6	253	14	0	0	6	0				479
1998	459	2	0	10	310	0											
1999	312	4	0														
2000	401																
2001	804																
2002	316																

Appendix B5. – Continued.

System: Nushagak River
Species: sockeye salmon

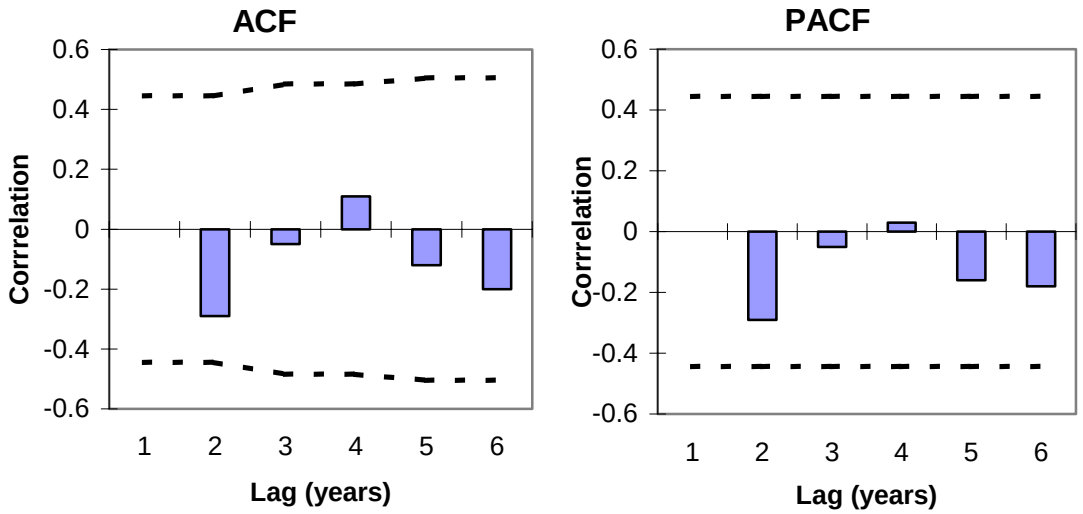
Data available for Aggregate Analysis (in thousands of fish).

Brood Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1956	1,220	0	0	48	1,160	0	1	1,318	36	0	4	36	0	0	0	0	2,603
1957	515	0	0	27	145	0	1	305	56	0	2	23	0	0	0	0	558
1958	1,286	2	1	3	2,253	1	3	782	128	0	1	72	0	0	0	0	3,248
1959	3,042	1	0	66	1,165	10	1	623	462	0	2	89	0	0	2	0	2,420
1960	1,673	9	7	13	1,697	0	2	1,755	175	0	5	176	1	0	0	0	3,840
1961	892	3	0	57	334	0	4	1,879	48	0	4	39	0	1	1	0	2,369
1962	952	4	2	28	1,035	1	5	671	126	0	7	54	0	0	0	0	1,932
1963	1,139	5	0	43	799	1	1	1,206	114	0	0	79	0	0	0	0	2,247
1964	1,370	6	1	21	635	1	0	995	486	0	0	125	0	0	2	0	2,272
1965	1,146	3	1	28	931	1	0	2,129	328	0	10	348	0	0	2	0	3,780
1966	1,713	3	7	60	1,161	0	4	1,917	58	0	9	89	0	1	1	0	3,310
1967	952	2	4	43	714	0	1	426	88	0	6	100	0	0	0	0	1,383
1968	997	6	1	10	570	0	8	974	6	0	13	38	0	0	0	0	1,626
1969	1,223	2	0	116	62	0	6	659	518	0	19	228	0	0	1	0	1,611
1970	2,040	1	2	11	1,673	1	6	1,914	433	0	2	194	0	0	0	0	4,236
1971	1,449	4	0	61	600	0	0	1,606	305	1	2	248	0	1	0	0	2,827
1972	541	11	1	57	930	0	7	1,326	79	0	78	164	0	0	0	0	2,653
1973	633	1	1	55	331	0	9	2,927	108	0	11	80	0	0	0	0	3,523
1974	2,287	2	3	40	3,549	5	9	2,747	777	0	21	108	0	0	0	0	7,261
1975	2,408	29	47	57	2,928	2	20	9,117	676	0	15	1,499	0	1	0	0	14,390
1976	1,515	16	5	124	3,258	6	12	7,018	833	0	68	761	0	0	0	0	12,103
1977	1,426	30	21	78	1,682	0	67	5,807	52	0	142	46	3	0	0	0	7,927
1978	3,628	18	0	436	1,560	3	149	2,138	888	0	14	117	0	1	0	0	5,323
1979	3,300	18	11	466	3,560	0	16	2,751	43	0	43	22	0	0	0	0	6,930
1980	8,788	19	0	447	558	0	67	1,593	260	0	5	314	0	0	0	0	3,263
1981	3,142	9	0	137	985	0	14	3,392	70	0	87	167	0	0	0	0	4,861
1982	2,053	35	4	358	743	0	49	2,092	133	0	76	31	0	0	0	0	3,520
1983	2,003	101	2	613	2,205	0	124	2,060	29	0	19	107	0	0	0	0	5,259
1984	1,892	10	0	226	678	0	33	2,548	89	0	39	65	0	1	0	0	3,691
1985	1,729	75	3	532	1,706	0	63	2,939	122	0	21	107	0	2	0	0	5,571
1986	2,242	78	2	876	1,529	0	60	4,877	96	0	209	158	0	0	0	0	7,886
1987	2,040	167	0	974	1,528	0	267	1,878	141	0	121	131	0	3	0	0	5,211
1988	1,630	73	1	555	2,016	0	125	3,907	143	0	79	78	0	0	0	0	6,979
1989	2,190	70	4	513	2,924	0	35	3,743	74	0	26	95	0	0	0	0	7,484
1990	2,144	63	1	774	1,299	1	108	2,890	487	0	17	322	0	4	1	0	5,966
1991	2,419	10	12	148	3,124	0	6	4,790	60	0	201	110	0	0	0	0	8,463
1992	2,286	95	1	555	2,669	0	13	2,472	107	0	50	88	0	1	0	0	6,050
1993	2,297	57	0	46	1,911	0	8	2,150	160	0	121	275	0	0	0	0	4,729
1994	2,450	0	10	43	3,186	1	2	3,504	547	0	12	171	0	0	0		7,476
1995	2,254	5	7	8	4,320	0	0	5,116	198	0	188	63	0				9,906
1996	2,562	0	0	6	3,379	0	5	6,708	7	0							
1997	2,024	4	0	211	278	0											
1998	2,431	2	3														
1999	2,270																
2000	2,117																
2001	2,679																

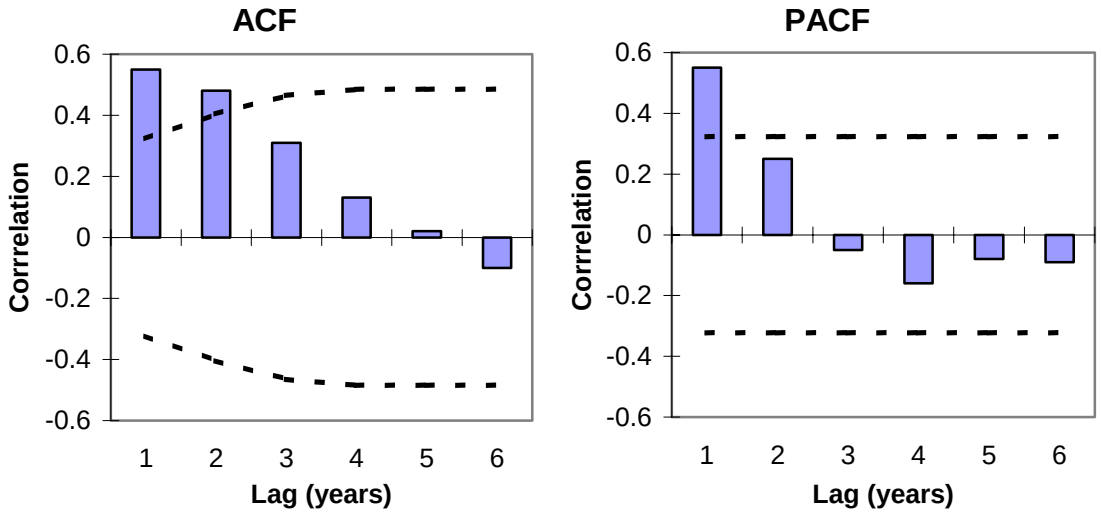
Appendix B5. – Continued.

System: Nushagak River
Species: sockeye salmon

ACF and PACF plots for Ricker stock-recruitment residuals, 1978-1997 brood years.



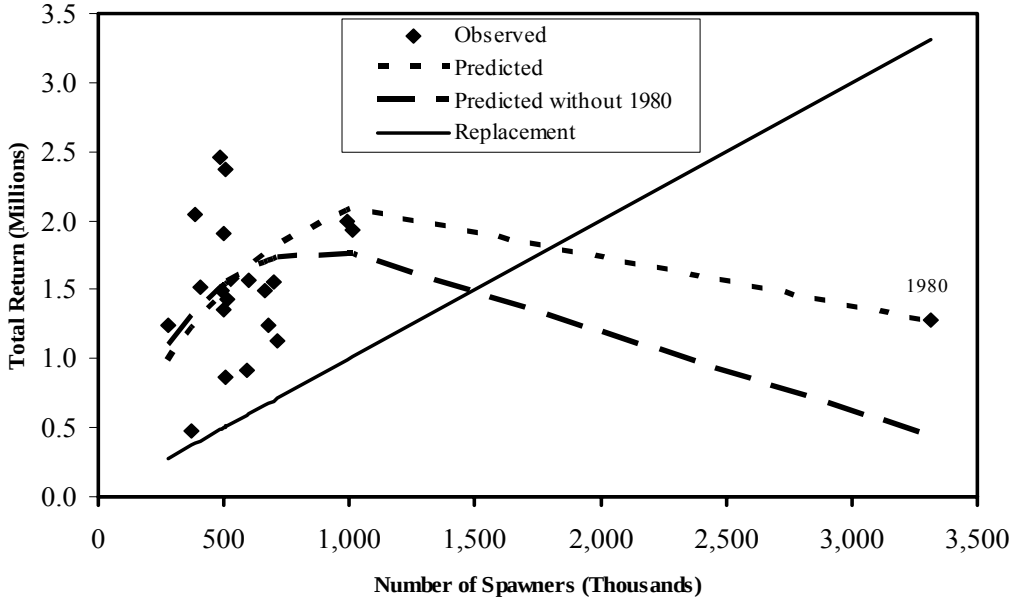
ACF and PACF plots for Ricker stock-recruitment residuals, Aggregate Analysis, 1956-1997 brood years.



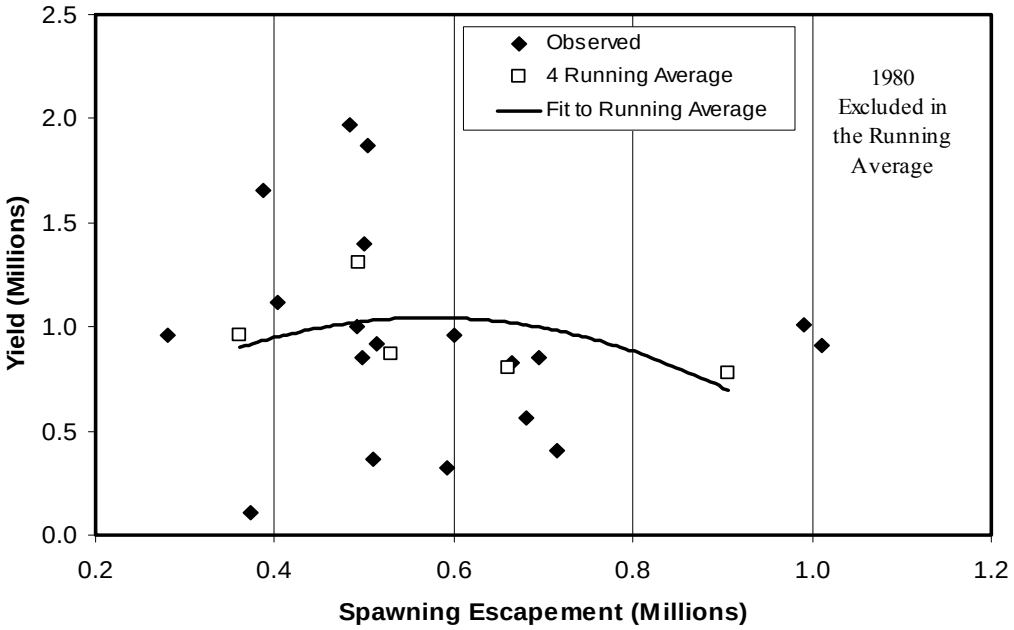
Appendix B5. – Continued.

System: Nushagak River
Species: sockeye salmon

Ricker stock-recruitment relationship, 1978-1997 brood years.



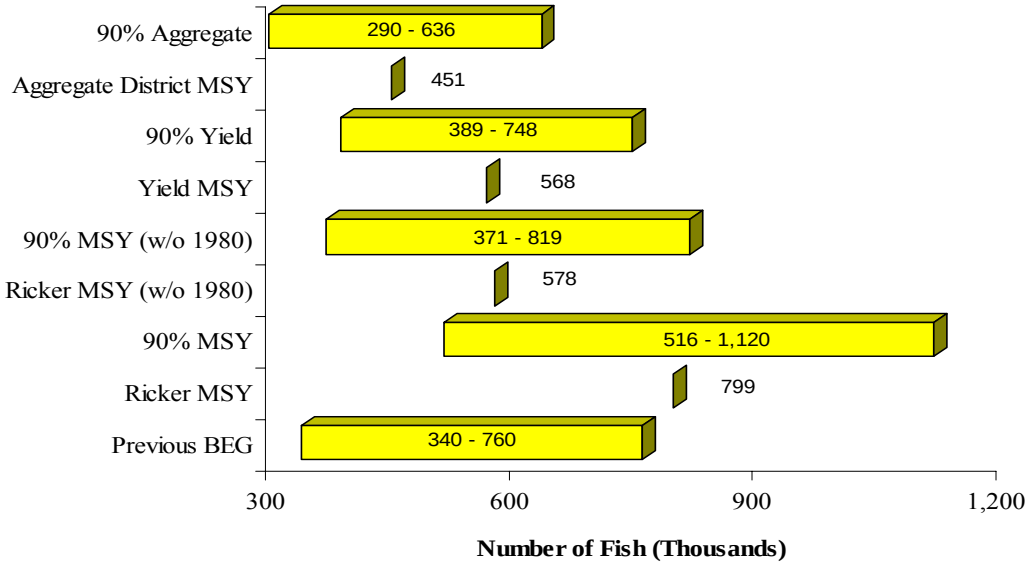
Stock-yield relationship, 1978-1997 brood years.



Appendix B5. – Continued.

System: Nushagak River
Species: sockeye salmon

Summary of current escapement goal and estimates of S_{MSY}.



Appendix B6. – Escapement goal for Togiak River sockeye salmon.

System: Togiak River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	100,000 – 200,000 (1997)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	100,000 – 250,000
Escapement Goal Type:	BEG
Escapement Estimation:	Tower counts from 1956 to present; 42 years of complete return data available
Summary:	
Data Quality	Excellent
Data Type	Tower counts; commercial harvest; age data
Methodology	Ricker stock-recruitment, yield analysis
Autocorrelation	Significant autoregressive correlation at lag-1
Years within recommended goal	28 out of 42
Comments	The analyses were conducted using years for which complete return data were available. All MSY models indicated that the upper range should be increased. The goal represents an estimate of total spawner abundance. The goal for the Togiak River system accounts for aerial survey counts (20,000 average) that are supplementary to the tower counts. Thus, the total Togiak River system escapement goal is 120,000 – 270,000 spawners.

Appendix B6. – Continued.

System: Togiak River
Species: sockeye salmon

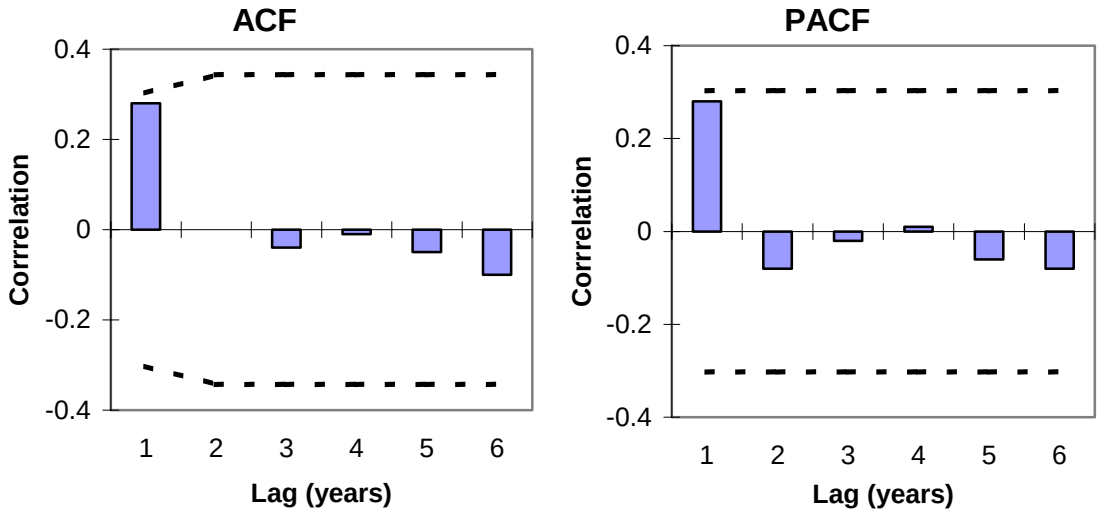
Data available for analysis of escapement goals (in thousands of fish).

Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1956	225	0	0	4	114	0	0	306	22	0	1	13	0	0	0	0	460
1957	25	2	0	5	48	0	0	70	20	0	0	36	1	0	0	0	182
1958	72	0	1	2	68	0	0	115	59	0	0	25	0	0	0	0	270
1959	210	0	0	0	141	0	0	92	56	0	0	7	0	0	0	0	296
1960	163	0	0	2	191	0	0	274	22	0	0	52	0	0	0	0	541
1961	122	1	0	3	85	0	0	216	15	0	1	19	0	0	0	0	340
1962	62	0	0	7	48	0	0	102	4	0	0	8	0	0	0	0	169
1963	116	0	0	2	43	0	0	65	18	0	0	24	0	0	0	0	152
1964	105	0	0	1	43	0	0	84	41	0	0	6	0	0	0	0	175
1965	96	0	0	2	154	0	0	181	31	0	0	37	0	0	0	0	405
1966	104	1	0	6	200	0	0	419	4	0	1	9	0	0	0	0	640
1967	81	1	0	6	18	0	0	99	16	0	1	40	0	0	0	0	181
1968	50	0	0	1	49	0	0	190	6	0	3	13	0	0	0	0	262
1969	117	0	0	5	28	0	0	142	25	0	3	13	0	0	0	0	216
1970	203	0	0	1	54	0	0	226	55	0	1	70	0	0	0	0	407
1971	200	0	0	4	106	0	0	317	62	0	1	68	0	0	0	0	558
1972	79	0	0	2	93	0	0	150	21	0	2	34	0	0	0	0	302
1973	107	1	0	10	151	0	0	442	18	0	1	31	0	0	0	0	654
1974	104	0	0	2	271	0	0	307	73	0	3	45	0	1	0	0	702
1975	181	1	0	7	195	0	0	848	87	0	2	59	0	0	0	0	1,199
1976	189	0	0	1	189	0	0	558	142	0	4	175	0	0	0	0	1,069
1977	163	0	0	5	232	0	0	617	14	0	4	14	0	0	0	0	886
1978	306	0	0	12	149	0	0	430	65	0	1	25	0	0	0	0	682
1979	198	1	0	1	270	0	0	293	12	0	2	5	0	0	0	0	584
1980	527	0	0	5	45	0	1	224	10	0	0	19	0	0	0	0	304
1981	307	2	0	11	53	0	0	245	15	0	1	16	0	0	0	0	343
1982	289	0	0	16	109	0	0	255	14	0	5	26	0	0	0	0	425
1983	213	1	0	3	285	0	2	924	9	0	2	21	0	0	0	0	1,247
1984	151	0	0	14	21	0	0	109	4	0	1	17	0	0	0	0	166
1985	153	0	0	7	35	0	0	194	35	0	1	77	0	1	0	0	350
1986	203	0	0	18	77	0	1	445	83	0	14	121	0	0	0	0	759
1987	278	0	0	7	190	0	1	575	31	0	7	81	0	0	0	0	892
1988	309	1	0	9	111	0	3	403	34	0	3	53	0	0	0	0	617
1989	104	0	0	36	132	0	1	328	7	0	1	41	0	0	0	0	546
1990	166	1	0	23	101	0	1	460	75	0	5	37	0	0	0	0	703
1991	254	1	3.2	3	189	0	1	429	28	0	8	29	0	0	0	0	691
1992	210	1	0	35	50	0	1	124	33	0	1	30	0	0	0	0	275
1993	189	0	0.3	4	64	0	0	229	6	0	4	15	0	0	0	0	322
1994	174	1	0.2	3	43	0	0	167	31	0	1	8	0	0	0	0	254
1995	211	0	0.6	6	341	0	1	1010	11	0	5	66	0	0	0	0	1,441
1996	187	1	0.3	9	87	0	326	987	4	0	8	22	1	0	0		1,445
1997	152	0	0	5	43	0	0	316	17	0	0	26	0				407
1998	175	0	0	2	55	0											
1999	196	0	0														
2000	352																
2001	303																
2002	179																

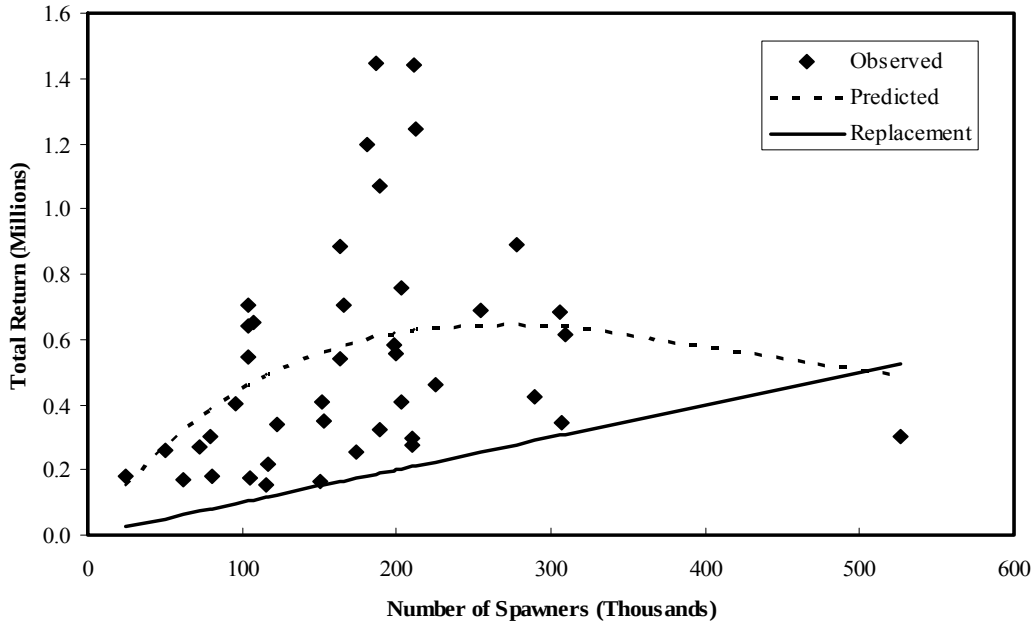
Appendix B6. – Continued.

System: Togiak River
Species: sockeye salmon

ACF and PACF plots for Ricker stock-recruitment residuals, 1956-1997 brood years.



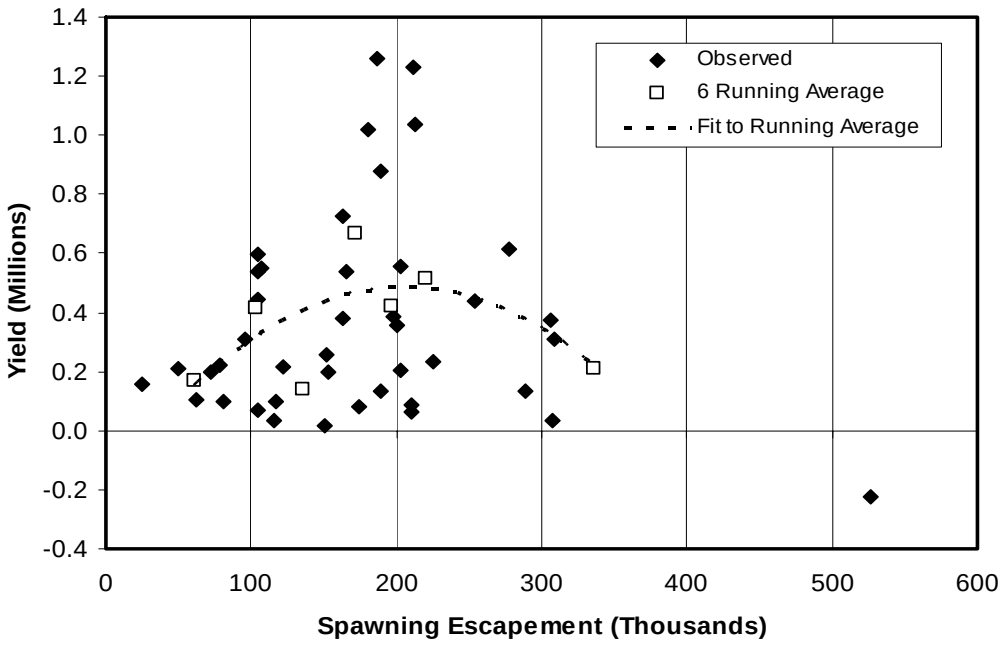
Ricker stock-recruitment relationship, 1956-1997 brood years.



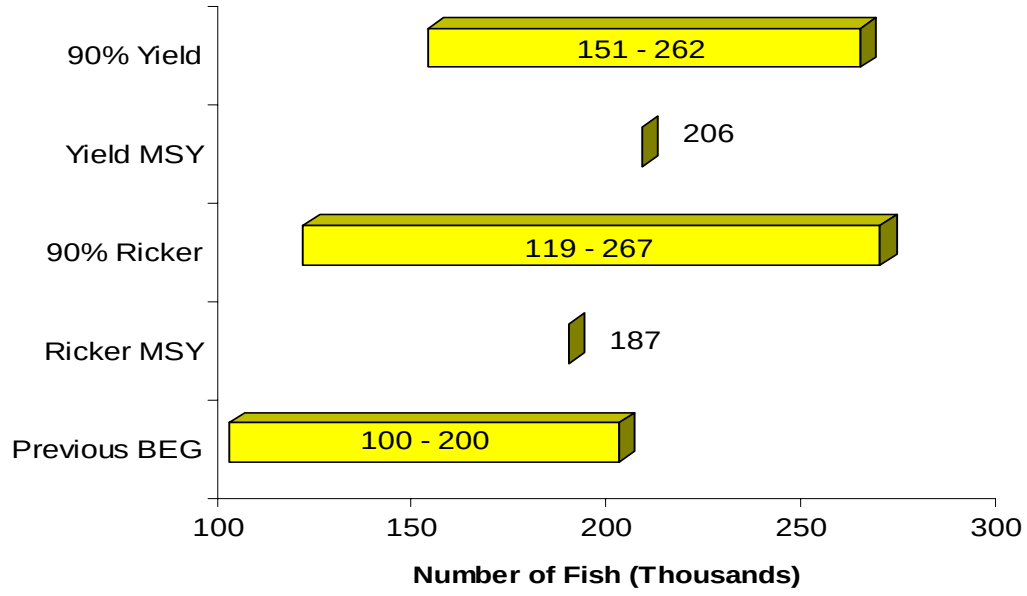
Appendix B6. – Continued.

System: Togiak River
Species: sockeye salmon

Stock-yield relationship, 1956-1997 brood years.



Summary of current escapement goal and estimates of S_{MSY}.



Appendix B7. – Escapement goal for Ugashik River sockeye salmon.

System: Ugashik River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	500,000 – 1,200,000 (1997)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	500,000 – 1,800,000
Escapement Goal Type:	BEG
Escapement Estimation:	Tower counts from 1956 to present; 42 years of complete return data available
Summary:	
Data Quality	Excellent
Data Type	Tower counts; commercial harvest; age data
Methodology	Ricker stock-recruitment, yield analysis
Autocorrelation	Significant autoregressive correlation at lag-1
Years within recommended goal	20 out of 42
Comments	The analyses were conducted using years for which complete return data were available. Two data sets were examined; the first included all 42 years of return data and the second included the last 24 years of return data. The second data set is from the more recent and productive time period and the committee felt this era best represented the current situation. Therefore, more focus went into the results from the shorter data set. From the shorter data set, all MSY models indicated that the lower and upper ranges should be increased. However, the yields from 500,000, the lower goal, through 3,500,000 were similar so the lower goal was not changed. The goal represents an estimate of total spawner abundance.

Appendix B7. – Continued.

System: Ugashik River
Species: sockeye salmon

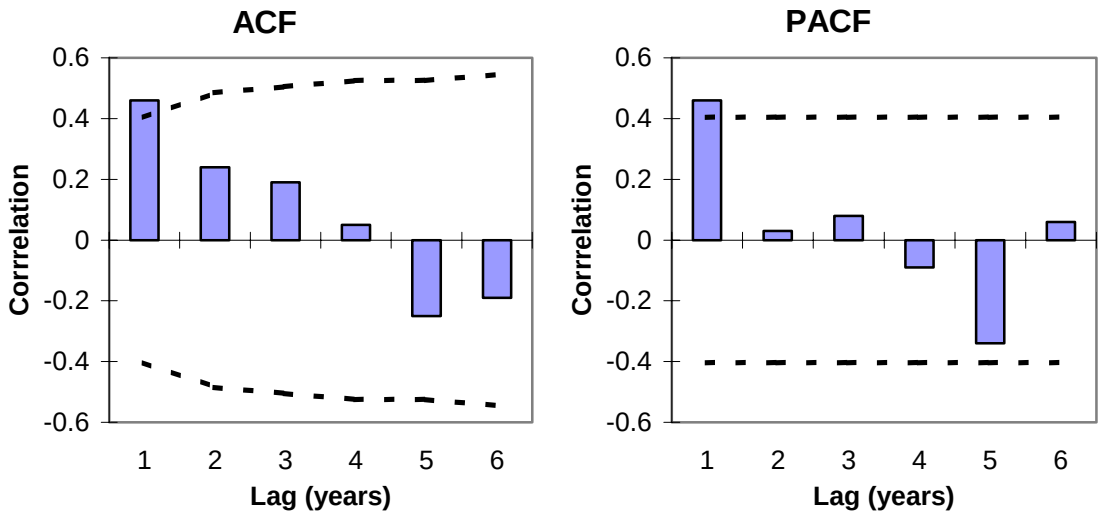
Data available for analysis of escapement goals (in thousands of fish).

Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1956	425	1	12	0	3,165	0	0	837	80	0	2	35	0	0	0	0	4,132
1957	215	0	0	1	35	0	0	105	354	0	2	100	4	0	2	0	603
1958	280	0	0	0	63	0	0	105	444	0	0	66	0	0	0	0	678
1959	219	0	0	0	18	0	0	38	310	0	0	132	0	0	1	0	499
1960	2,304	0	0	0	674	11	0	296	1,563	0	0	487	0	0	0	0	3,031
1961	349	0	0	3	240	2	0	500	247	0	1	120	0	0	0	0	1,113
1962	255	0	0	2	77	2	0	130	185	0	0	27	0	0	0	0	423
1963	388	0	0	0	13	0	0	21	91	0	0	23	0	0	0	0	148
1964	473	0	0	0	31	9	0	16	245	0	0	18	0	0	2	0	321
1965	997	0	0	0	86	2	0	38	249	0	1	162	1	0	0	0	539
1966	704	1	0	2	723	0	0	1,478	90	0	0	21	0	0	0	0	2,315
1967	239	0	0	0	56	0	0	50	44	0	0	34	0	0	0	0	184
1968	71	0	0	0	14	0	0	7	15	0	0	3	0	0	0	0	39
1969	160	0	0	0	4	0	0	5	53	0	0	26	2	0	2	0	92
1970	735	0	0	0	4	1	0	2	256	0	1	28	2	0	1	0	295
1971	530	0	0	0	178	0	0	236	290	0	0	130	0	0	1	0	835
1972	79	0	0	0	35	0	0	58	119	0	0	41	2	0	3	0	258
1973	39	0	0	1	16	0	0	8	17	0	0	46	4	0	0	0	92
1974	62	0	0	0	13	10	0	15	602	0	0	83	2	0	0	0	725
1975	429	0	3	0	1,484	4	0	575	1,721	0	0	325	2	1	0	0	4,115
1976	356	0	0	2	2,027	58	0	1,527	1,248	0	7	437	0	0	3	0	5,309
1977	202	0	2	18	585	0	0	1,614	266	0	10	186	6	1	4	0	2,692
1978	82	0	0	5	247	7	0	413	863	0	6	523	1	0	0	0	2,065
1979	1,707	0	20	0	3,076	8	0	851	1,471	0	14	562	0	5	0	0	6,007
1980	3,335	0	1	13	1,183	39	0	2,309	3,371	0	10	850	3	2	0	0	7,781
1981	1,328	0	2	10	1,603	4	0	2,632	2,278	0	4	933	1	1	0	0	7,468
1982	1,186	0	1	15	423	1	1	713	606	0	9	737	0	2	0	0	2,508
1983	1,001	0	0	10	650	6	1	342	632	0	3	319	1	1	0	0	1,965
1984	1,270	0	0	5	472	55	0	568	3,635	0	13	709	3	0	4	0	5,464
1985	1,006	2	1	6	508	2	0	721	978	0	4	469	0	5	0	0	2,695
1986	1,016	5	1	46	503	1	0	2,427	1,874	0	71	1,750	4	15	0	0	6,696
1987	687	7	1	9	828	11	0	1,626	1,875	0	25	2,310	10	20	24	0	6,745
1988	654	1	2	1	463	27	0	692	2,144	0	37	2,252	22	3	7	0	5,650
1989	1,713	3	7	7	694	14	0	391	2,479	0	12	955	6	1	4	0	4,573
1990	749	0	1	13	345	15	2	709	2,302	0	2	1,218	2	2	0	0	4,611
1991	2,482	1	6	0	2,034	1	0	3,167	597	0	14	326	0	4	0	0	6,151
1992	2,195	6	3	49	191	4	1	597	1,013	0	1	827	0	10	1	0	2,703
1993	1,413	1	2	2	265	7	0	352	241	0	17	198	0	0	1	0	1,086
1994	1,095	0	12	4	333	12	0	327	689	0	6	274	1	2	0	0	1,660
1995	1,321	3	18	7	2,808	1	0	1,562	185	0	19	82	0	1	0	0	4,686
1996	692	0	0	40	231	0	3	978	36	0	16	83	1	0	0		1,388
1997	657	1	0	2	234	0	0	693	1,561	0	0	560	0				3,051
1998	925	0	1	0	205	1											
1999	1,662	0	6														
2000	638																
2001	866																
2002	906																

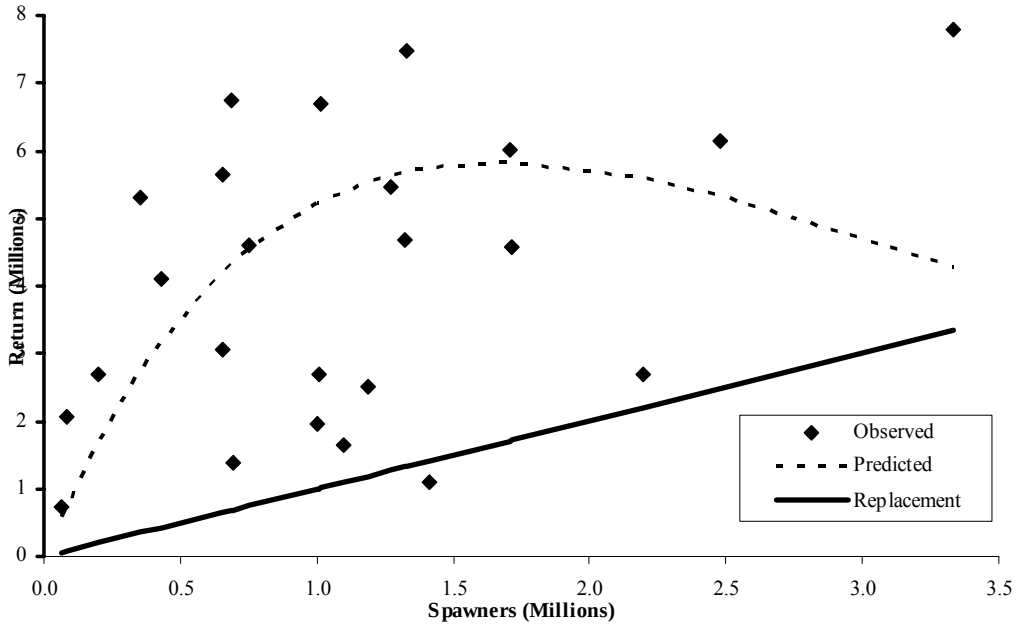
Appendix B7. – Continued.

System: Ugashik River
Species: sockeye salmon

ACF and PACF plots for Ricker stock-recruitment residuals, 1974-1997 brood years.



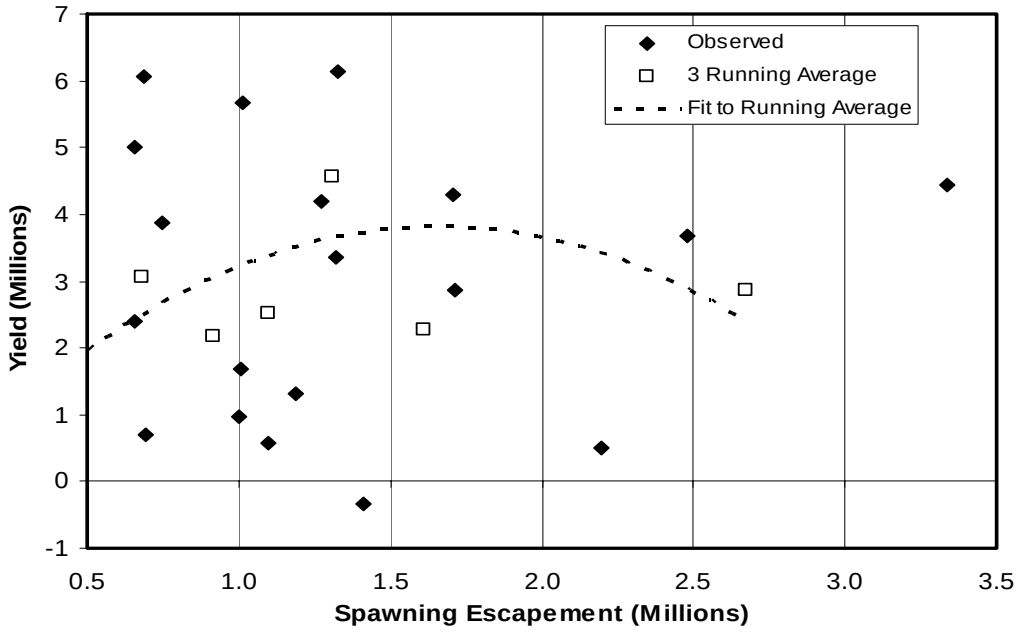
Ricker stock-recruitment relationship, 1974-1997 brood years.



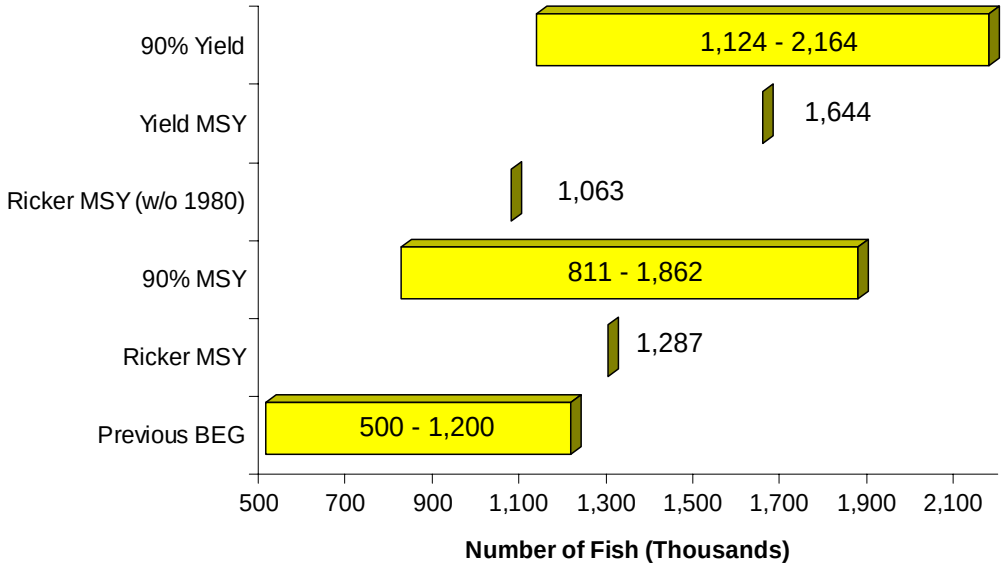
Appendix B7. – Continued.

System: Ugashik River
Species: sockeye salmon

Stock-yield relationship, 1974-1997 brood years.



Summary of current escapement goal and estimates of S_{MSY}, 1974-1997.



Appendix B8. – Escapement goal for Wood River sockeye salmon.

System: Wood River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	700,000 – 1,500,000 (1984)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	Same
Escapement Goal Type:	BEG
Escapement Estimation:	Tower counts from 1956 to present; 42 years of complete return data available
Summary:	
Data Quality	Excellent
Data Type	Tower counts; commercial harvest; age data
Methodology	Ricker stock-recruitment (standard brood table and Nushagak District aggregate brood table), yield analysis
Autocorrelation	Significant autoregressive correlation at lag-1 (all Ricker models)
Years within recommended goal	26 out of 41
Comments	The analyses were conducted using years for which complete return data were available. None of the MSY models suggested that the current goal should change. The goal represents an estimate of total spawner abundance.

Appendix B8. – Continued.

System: Wood River
Species: sockeye salmon

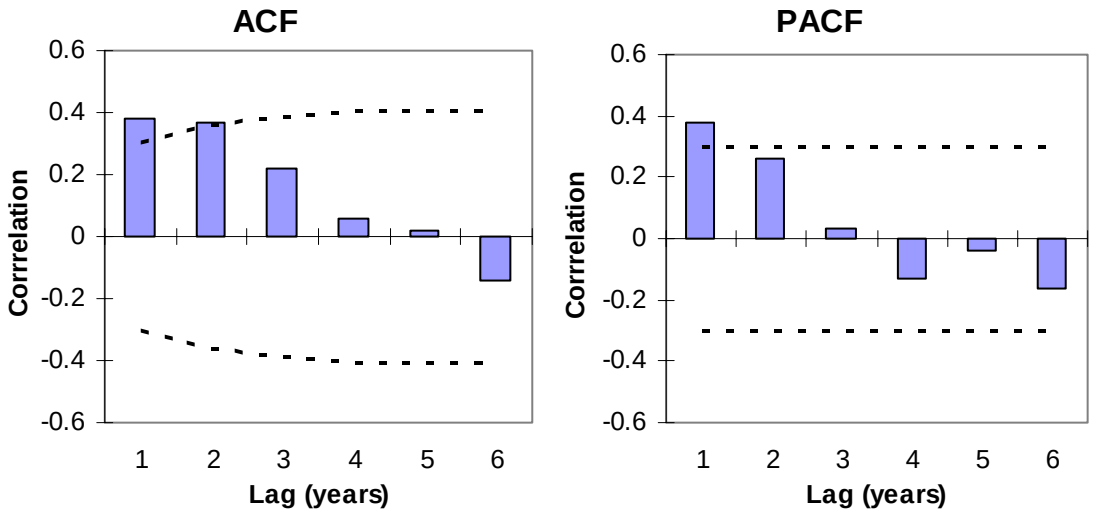
Data available for analysis of escapement goals (in thousands of fish).

Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1956	773	0	0	48	774	0	0	627	24	0	0	0	0	0	0	0	1,473
1957	289	0	0	21	136	0	0	257	35	0	0	0	0	0	0	0	449
1958	960	0	1	0	2,145	1	0	389	75	0	0	32	0	0	0	0	2,643
1959	2,209	0	0	1	979	10	0	398	359	0	1	55	0	0	2	0	1,805
1960	1,016	0	6	0	1,474	0	0	1,039	106	0	2	105	1	0	0	0	2,733
1961	461	0	0	10	255	0	0	1,183	24	0	2	20	0	1	1	0	1,496
1962	874	1	2	0	992	1	2	340	116	0	6	43	0	0	0	0	1,503
1963	721	0	0	0	536	1	0	769	76	0	0	46	0	0	0	0	1,428
1964	1,076	0	1	6	452	0	0	347	338	0	0	74	0	0	2	0	1,220
1965	675	2	1	8	472	1	0	999	90	0	0	213	0	0	1	0	1,787
1966	1,209	0	7	29	974	0	0	988	46	0	7	69	0	0	1	0	2,121
1967	516	0	3	21	642	0	0	269	75	0	2	80	0	0	0	0	1,092
1968	649	0	1	0	514	0	0	565	5	0	4	19	0	0	0	0	1,108
1969	604	0	0	4	57	0	0	445	201	0	10	116	0	0	0	0	833
1970	1,162	0	2	0	1,539	0	0	1,002	231	0	0	26	0	0	0	0	2,800
1971	851	3	0	18	456	0	0	576	198	0	1	49	0	0	0	0	1,301
1972	431	2	1	22	779	0	0	631	32	0	20	27	0	0	0	0	1,514
1973	330	1	1	0	213	0	0	1,148	74	0	3	44	0	0	0	0	1,484
1974	1,709	0	3	6	2,956	4	0	1,698	421	0	5	71	0	0	0	0	5,164
1975	1,270	13	47	12	1,592	2	0	1,977	406	0	2	734	0	0	0	0	4,785
1976	817	0	3	0	2,278	3	0	2,589	572	0	10	265	0	0	0	0	5,720
1977	562	0	20	0	1,029	0	0	2,173	40	0	0	26	2	0	0	0	3,290
1978	2,267	0	0	0	1,364	3	0	1,029	784	0	12	96	0	0	0	0	3,288
1979	1,706	0	10	0	2,643	0	0	1,491	24	0	1	13	0	0	0	0	4,182
1980	2,969	0	0	0	453	0	0	978	72	0	1	101	0	0	0	0	1,605
1981	1,233	0	0	0	626	0	0	1,137	60	0	0	86	0	0	0	0	1,909
1982	976	0	4	0	522	0	0	765	121	0	12	14	0	0	0	0	1,438
1983	1,361	0	1	5	1,940	0	2	1,154	15	0	2	75	0	0	0	0	3,194
1984	1,003	0	0	0	586	0	2	1,340	32	0	15	23	0	0	0	0	1,998
1985	939	8	3	15	1,127	0	1	1,390	29	0	2	12	0	1	0	0	2,588
1986	819	7	2	25	1,179	0	1	1,970	70	0	12	64	0	0	0	0	3,330
1987	1,337	25	0	30	1,334	0	14	756	98	0	8	92	0	1	0	0	2,358
1988	867	4	1	8	1,613	0	3	1,425	90	0	15	34	0	0	0	0	3,193
1989	1,186	1	4	16	2,293	0	0	1,922	13	0	2	39	0	0	0	0	4,290
1990	1,069	10	1	10	1,104	1	3	1,208	286	0	2	169	0	0	0	0	2,794
1991	1,160	0	12	9	2,633	0	0	2,466	54	0	65	71	0	0	0	0	5,310
1992	1,286	10	1	57	2,398	0	2	1,674	90	0	0	49	0	0	1	0	4,282
1993	1,176	14	0	3	1,715	0	9	1,161	129	0	3	191	0	0	0	0	3,225
1994	1,472	0	10	0	2,747	1	0	1,993	448	0	2	91	0	0	0	0	5,292
1995	1,482	1	5	0	3,524	0	0	2,594	149	0	61	35	0	0	0	0	6,369
1996	1,650	0	0	0	2,705	0	0	3,676	3	0	57	13	0	0	0		6,454
1997	1,512	4	0	63	174	0	4	668	164	0	0	69	0				1,146
1998	1,756	0	3	11	2,895	1											
1999	1,512	4	2														
2000	1,300																
2001	1,459																
2002	1,284																

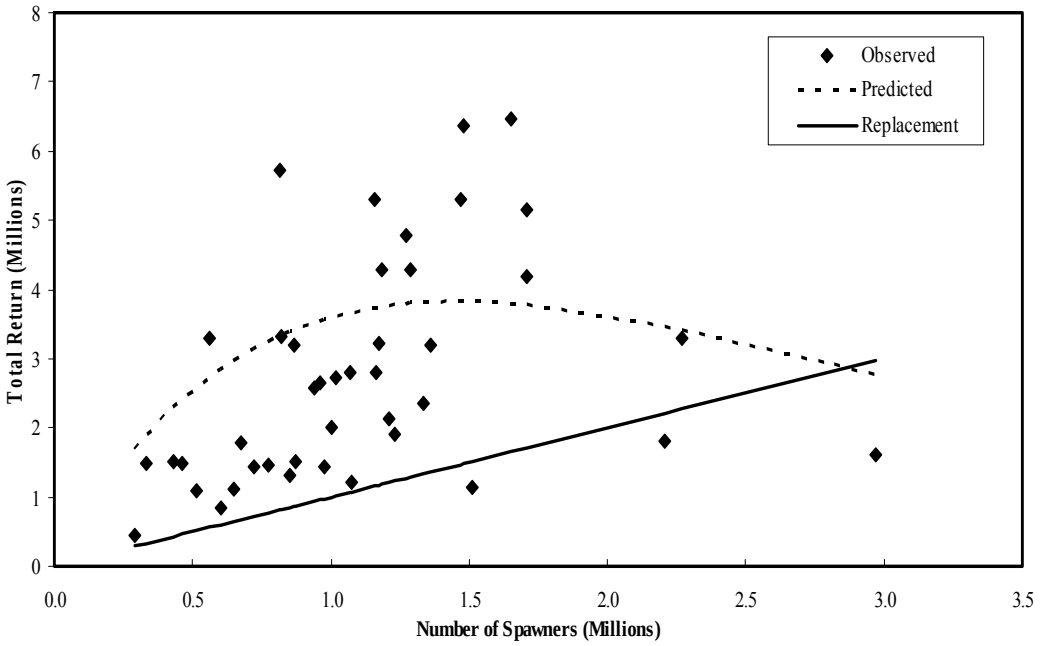
Appendix B8. – Continued.

System: Wood River
Species: sockeye salmon

ACF and PACF plots for Ricker stock-recruitment residuals, 1956-1997 brood years.



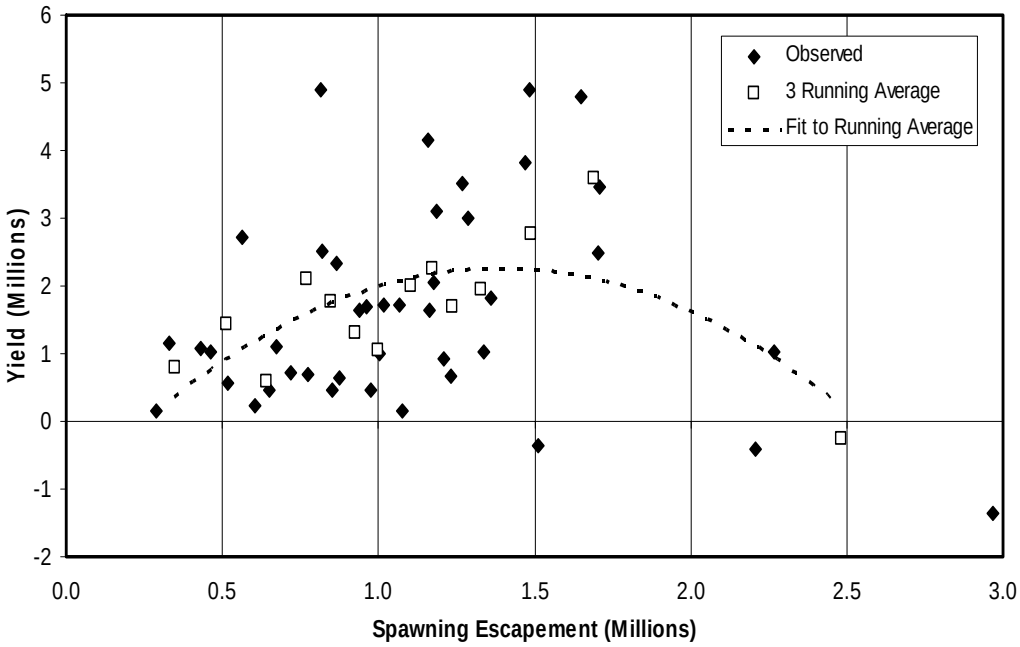
Ricker stock-recruitment relationship, 1956-1997 brood years.



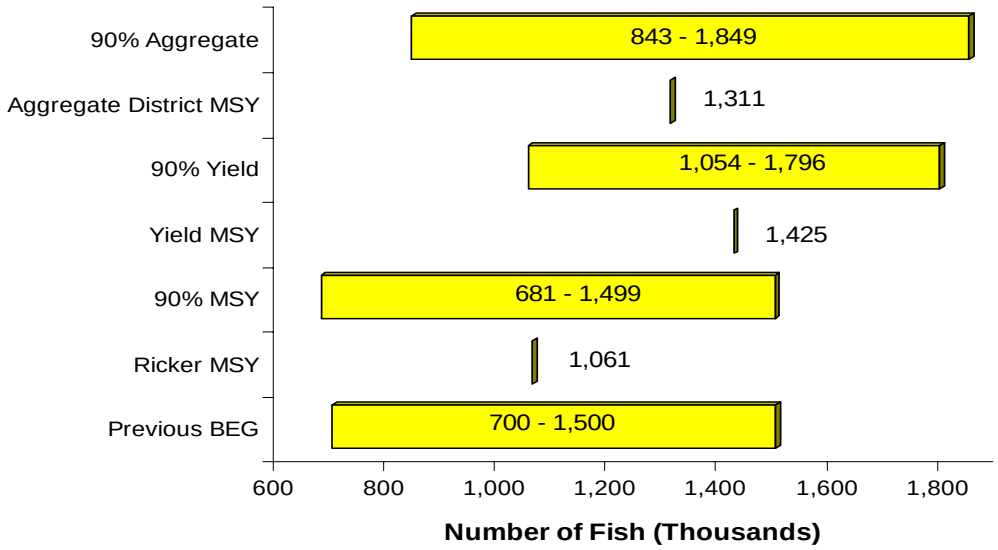
Appendix B8. – Continued.

System: Wood River
Species: sockeye salmon

Stock-yield relationship, 1956-1997 brood years.



Summary of current escapement goal and estimates of S_{MSY}.



Appendix B9. – Escapement goal for Alagnak River sockeye salmon.

System: Alagnak River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	170,000 – 200,000
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	100,000 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Tower counts from 1956-1976; expanded aerial survey counts since 1977
Summary:	
Data Quality	Fair to Excellent
Data Type	Tower; aerial survey; age data
Methodology	Risk analysis
Autocorrelation	Significant autoregressive correlation at lag-1
Years within recommended goal	40 out of 47
Comments	This stock has SEG quality data, and is passively managed and coincidentally harvested. Therefore, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

Appendix B9. – Continued.

System: Alagnak River
Species: sockeye salmon

Data available for analysis of escapement goals (in thousands of fish).

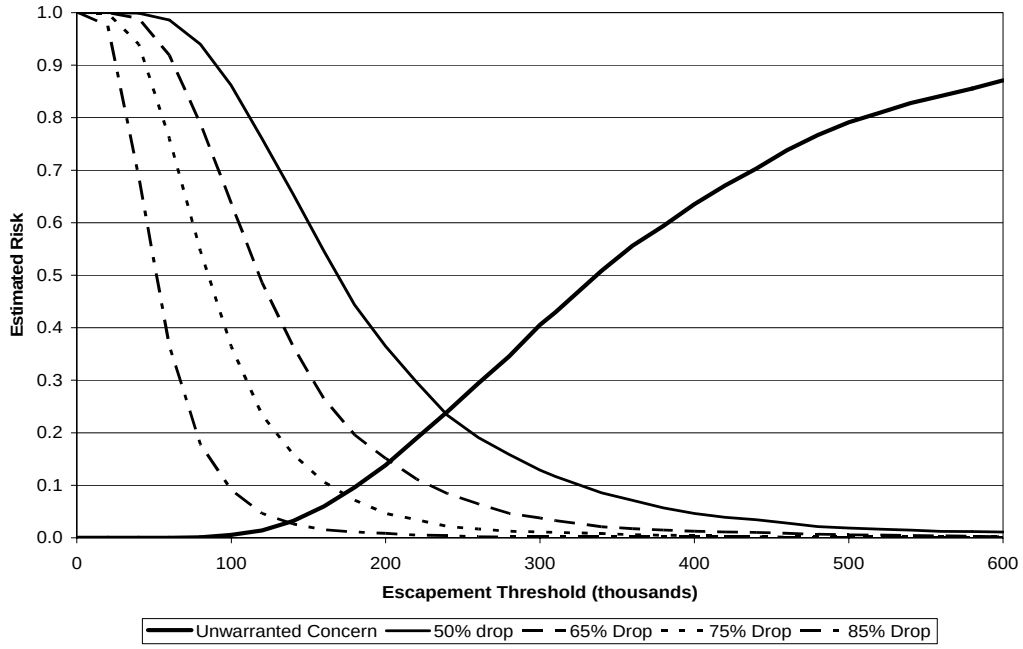
Brood		Return by Age Class															
Year	Escapement	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	3.4	Total
1956	784	5	0	0	1,885	0	0	459	0	0	0	38	3	0	0	0	2,390
1957	127	0	0	0	5	0	0	23	43	0	0	13	0	0	1	0	85
1958	95	0	0	0	43	0	0	26	27	0	0	52	0	0	0	0	148
1959	825	0	0	0	302	0	0	265	122	0	0	76	1	0	2	0	768
1960	1,241	0	0	0	105	0	0	185	135	0	0	31	0	0	0	0	456
1961	90	0	10	1	89	1	0	185	7	0	0	0	0	0	0	0	293
1962	91	0	19	0	129	0	0	91	3	0	0	19	1	0	0	0	262
1963	203	0	0	0	199	1	0	140	34	0	0	1	0	0	0	0	375
1964	249	0	5	0	100	2	0	98	113	0	0	17	0	0	0	0	336
1965	175	0	6	0	104	1	0	161	10	0	0	17	0	0	0	0	299
1966	174	0	13	0	282	0	0	262	12	0	0	11	0	0	0	0	580
1967	203	0	9	8	291	1	0	51	46	0	0	7	0	0	0	0	413
1968	194	3	5	0	127	0	0	40	2	0	0	3	0	0	0	0	180
1969	182	0	0	0	4	1	0	54	105	0	0	25	0	0	0	0	189
1970	177	0	0	0	73	0	0	71	6	0	0	2	0	0	0	0	152
1971	187	0	2	0	26	0	0	28	31	0	0	37	0	0	2	0	126
1972	151	0	1	0	91	0	0	17	7	0	0	14	0	0	0	0	130
1973	35	0	0	0	97	1	0	130	18	0	0	2	0	0	0	0	248
1974	215	0	4	0	292	5	0	18	128	0	0	8	0	0	0	0	455
1975	100	0	15	0	415	0	0	340	3	0	1	1	0	0	0	0	775
1976	82	0	26	0	211	0	0	168	20	0	0	55	0	0	0	0	480
1977	100	0	27	0	141	1	0	700	0	0	4	9	0	0	0	0	881
1978	229	0	1	0	102	0	0	68	39	0	0	147	0	0	0	0	357
1979	294	0	3	2	459	2	0	297	32	0	0	3	0	0	0	0	798
1980	298	0	0	0	103	0	0	211	13	0	2	9	0	1	0	0	339
1981	82	0	0	0	55	0	0	171	53	0	2	11	0	0	0	0	292
1982	239	0	0	0	172	0	0	142	4	0	0	3	0	0	0	0	321
1983	96	0	0	0	148	0	0	131	33	0	0	3	0	0	0	0	315
1984	215	0	1	0	159	0	0	146	42	0	0	23	0	0	0	0	371
1985	118	0	3	0	357	0	0	113	92	0	0	8	0	0	0	0	574
1986	230	0	1	0	344	0	0	267	193	0	0	8	0	0	0	0	813
1987	154	0	0	0	158	0	0	170	172	0	3	80	0	0	0	0	583
1988	195	0	1	0	154	0	0	148	279	0	0	43	0	0	0	0	625
1989	197	0	5	0	354	2	0	172	178	0	0	16	0	0	0	0	727
1990	169	0	2	0	262	0	0	124	330	0	0	237	0	0	0	0	955
1991	278	0	0	0	200	4	0	220	165	0	0	0	0	0	0	0	589
1992	225	0	2	0	98	0	0	73	65	0	0	10	0	0	1	0	249
1993	348	0	4	0	127	0	0	161	83	0	2	47	0	0	0	0	424
1994	243	0	1	0	162	2	0	273	40	0	0	41	0	0	0	0	519
1995	216	0	4	0	711	0	0	195	127	0	6	26	0	0	0	0	1,069
1996	307	0	3	0	408	0	0	303	10	0	2	9	0	0	0		735
1997	218	0	2	0	66	0	0	119	51	0	0	0	0				238
1998	252	0	2	0	162	1											
1999	464	0	4														
2000	451																
2001	267																
2002	761																

Note: the 1956-1976 escapements are based on Alagnak tower counts and the 1977-2001 escapements are based on aerial surveys.

Appendix B9. – Continued.

System: Alagnak River
Species: sockeye salmon

Risk analysis summary showing the risk of an unwarranted concern and the estimated risk that a drop in various levels of mean escapement would not be detected.



Appendix B10. – Escapement goal for Kulukak River sockeye salmon.

System: Kulukak River
Species: sockeye salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	None
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	8,000 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Expanded aerial survey counts since 1961
Summary:	
Data Quality	Poor
Data Type	Aerial survey; no age data
Methodology	Risk analysis
Autocorrelation	Significant autoregressive correlation at lag-1
Years within recommended goal	40 out of 47
Comments	For stocks that are passively managed and coincidentally harvested, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years.

Appendix B10. – Escapement goal for Kulukak River sockeye salmon.

System: Kulukak River
Species: sockeye salmon

Data available for analysis of escapement goals.

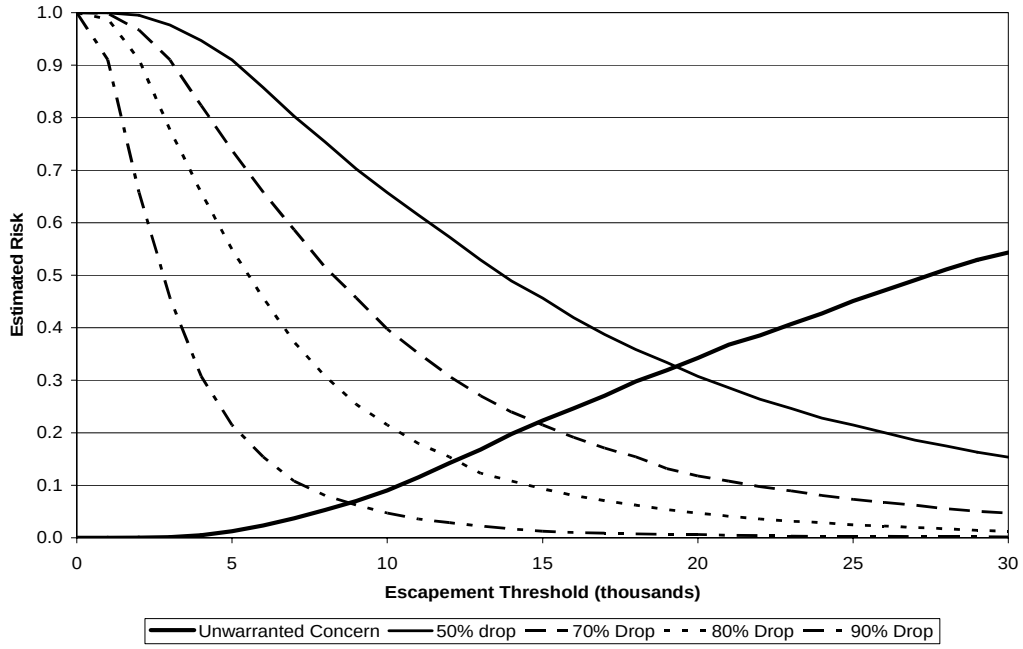
Year	Escapement	ln(Escapement)	Harvest
1961	5,200	8.56	3,373
1962	9,600	9.17	672
1963	11,400	9.34	554
1964	9,800	9.19	8,286
1965	16,300	9.70	3,265
1966	18,800	9.84	7,263
1967	10,000	9.21	24,379
1968	6,500	8.78	2,618
1969	8,400	9.04	3,411
1970	10,000	9.21	
1971	13,000	9.47	7,927
1972	3,400	8.13	17,244
1973	800	6.68	15,551
1974	4,900	8.50	13,615
1975	8,600	9.06	3,821
1976	11,200	9.32	4,822
1977	40,100	10.60	16,252
1978	33,900	10.43	29,668
1979	26,600	10.19	66,629
1980	45,700	10.73	42,811
1981	58,780	10.98	19,246
1982	52,750	10.87	13,952
1983	26,970	10.20	55,906
1984	49,800	10.82	96,709
1985	36,600	10.51	44,120
1986	42,800	10.66	100,466
1987	37,800	10.54	45,401
1988	31,700	10.36	143,112
1989	20,840	9.94	14,116
1990	49,600	10.81	27,311
1991	23,900	10.08	33,425
1992	26,440	10.18	108,358
1993	31,800	10.37	58,616
1994	29,740	10.30	76,781
1995	14,620	9.59	76,056
1996	18,980	9.85	76,833
1997	7,950	8.98	49,277
1998	12,950	9.47	76,332
1999	12,300	9.42	38,662
2000	22,350	10.01	67,612
2001	17,280	9.76	9,532
2002			
Mean	22,443	9.73	37,600
St. dev.	15,370	0.87	35,558
Median	18,800	9.84	25,845

Note: the harvest includes commercial, sport, and subsistence.

Appendix B10. – Escapement goal for Kulukak River sockeye salmon.

System: Kulukak River
Species: sockeye salmon

Risk analysis summary showing the risk of an unwarranted concern and the estimated risk that a drop in various levels of mean escapement would not be detected.



APPENDIX C.
SUPPORTING INFORMATION FOR CHUM SALMON ESCAPEMENT GOALS OF BRISTOL BAY

Appendix C1. – Escapement goal for Nushagak River chum salmon.

System: Nushagak River
Species: chum salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	None
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	190,000 minimum
Escapement Goal Type:	SEG
Escapement Estimation:	Sonar counts through July 20 since 1980; 19 years of complete return data available
Summary:	
Data Quality	Good
Data Type	Sonar escapement estimates; commercial harvest; age data
Methodology	Risk analysis
Autocorrelation	Not Significant
Years within recommended goal	13 out of 19
Comments	For stocks that are passively managed and coincidentally harvested, a risk analysis approach was taken to alert managers to potential changes in productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years. Escapement sonar counts are through July 20 when the project annually terminates.

Appendix C1. – Continued.

System: Nushagak River
Species: chum salmon

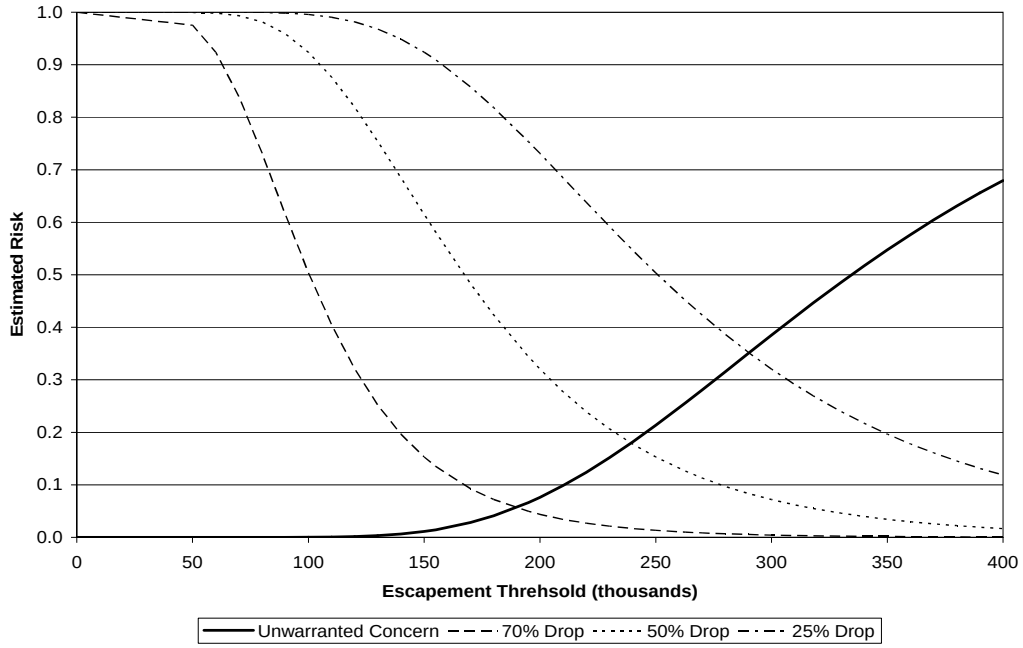
Data available for analysis of escapement goals.

Brood Year	Escapement	ln(Escapement)
1980	327,344	12.69877
1981	143,324	11.87286
1982	206,769	12.23936
1983	84,866	11.34883
1984	354,355	12.77805
1985	193,541	12.17324
1986	160,480	11.98592
1987	138,229	11.83667
1988	171,474	12.05219
1989	363,351	12.80312
1990	293,800	12.59065
1991	275,737	12.5272
1992	301,813	12.61756
1993	214,392	12.27556
1994	368,449	12.81706
1995	209,789	12.25386
1996	220,005	12.30141
1997	59,869	10.99991
1998	290,903	12.58075
1999	233,392	12.36047
2000	136,781	11.82614
2001	509,436	13.14106
2002	400,871	12.90139
Mean	246,042	12.30
St. dev.	109504	0.51
Median	220,005	12.30

Appendix C1. – Continued.

System: **Nushagak River**
Species: **chum salmon**

Risk analysis summary showing the risk of an unwarranted concern and the estimated risk that a drop in various levels of mean escapement would not be detected; chum salmon counts through July 20.



APPENDIX D.
SUPPORTING INFORMATION FOR COHO SALMON ESCAPEMENT GOALS OF BRISTOL BAY

Appendix D1. – Escapement goal for Togiak River coho salmon.

System: Togiak River
Species: coho salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	50,000 (1986)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	21,000 – 63,000
Escapement Goal Type:	SEG
Escapement Estimation:	Expanded aerial survey counts since 1980
Summary:	
Data Quality	Fair
Data Type	Aerial survey; return estimates not available
Methodology	Percentile approach
Contrast	20.8
Criteria for SEG	High contrast
Percentiles	25-75
Years within recommended goal	8 out of 15
Comments	This stock is actively managed so a risk analysis was not appropriate. Instead, escapement goal ranges were estimated according to the percentile algorithm (Bue and Hasbrouck 2001).

Appendix D1. – Continued.

System: Togiak River
Species: coho salmon

Data available for analysis of escapement goals.

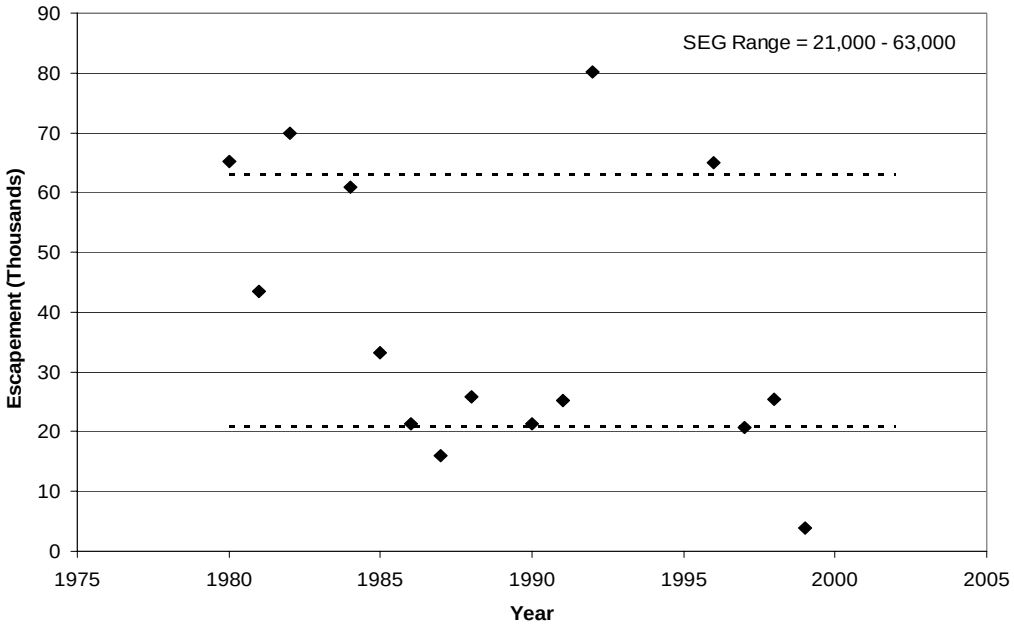
Year	Escapement [b]	ln(Escapement)	Harvest [a]
1980	65130	11.08	113287
1981	43,500	10.68	21,823
1982	69,900	11.15	109,824
1983			6,606
1984	60,840	11.02	116,585
1985	33,210	10.41	37,265
1986	21,400	9.97	31,381
1987	16,000	9.68	3,067
1988	25,770	10.16	10,774
1989			37,206
1990	21,390	9.97	3,774
1991	25,260	10.14	5,587
1992	80,100	11.29	5,400
1993			13,686
1994			89,963
1995			10,021
1996	64,980	11.08	59,950
1997	20,625	9.93	4,016
1998	25,335	10.14	53,793
1999	3,855	8.26	3,979
2000			3,940
2001			694
2002			739
Mean	38,486	10.33	32,320
St. dev.	23,605	0.78	39,229
Median	25,770	10.16	10,774

[a] Includes commercial, sport, and subsistence harvests.
[b] Expanded aerial survey counts.

Appendix D1. – Continued.

System: Togiak River
Species: coho salmon

Observed escapement by year (solid diamonds) and recommended SEG range (dashed lines).



Appendix D2. – Escapement goal for Nushagak River coho salmon.

System: Nushagak River
Species: coho salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	50,000 – 100,000 (1992)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	Dropped
Escapement Goal Type:	None
Escapement Estimation:	Sonar counts from 1980 to present; 17 years of complete return data available
Summary:	
Data Quality	Good
Data Type	Sonar escapement estimates; sport, subsistence, and commercial harvest; age data
Methodology	Ricker stock-recruitment, yield analysis
Autocorrelation	No significant autocorrelation
Years within recommended goal	Not applicable
Comments	The analyses were conducted using years for which complete return data were available. The goal was dropped because the Nushagak River sonar project now terminates on July 20 due to budget reductions and the majority of the escapement occurs after this date. Given permanent funding and a return to counting through at least August 17, model estimates of MSY suggest that the previous goal should not change.

Appendix D2. – Continued.

System: Nushagak River
Species: coho salmon

Data available for analysis of escapement goals.

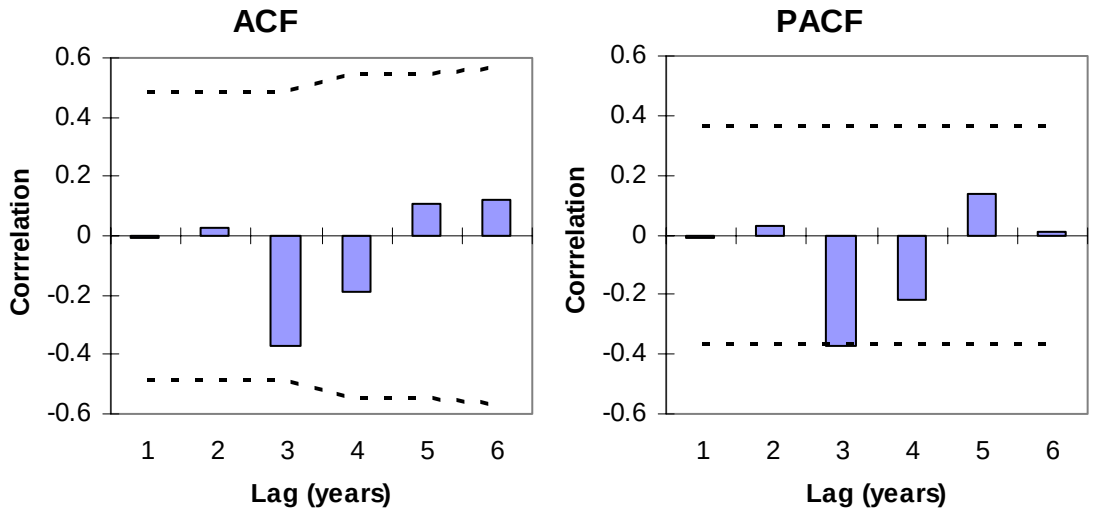
Brood Year	Escapement [3]	Returns By Age Class 1.1	2.1	3.1	1.2	2.2	Total
1980	95,411	13,272	389,742	0	1,465	2,621	407,100
1981	141,468	12,734	81,249	503	1,751	503	96,740
1982	294,151	28,830	117,625	1,695	0	0	148,150
1983	36,885	9,192	30,480	9,479	0	0	49,151
1984	140,804	10,160	150,147	4,743	0	0	165,050
1985	82,258	30,656	148,867	8,679	0	71	188,273
1986	45,483	15,092	137,380	0	0	0	152,472
1987	21,268	7,876	50,387	4,811 1/		0	63,074
1988	130,171	7,067	78,406 1/	1,380	0	0	86,853
1989	81,107	8,108 1/	60,069	9,003	0	173	77,353
1990	140,500	0	79,123	2,699	0	0	81,822
1991	37,584	3,636	49,317	5,071	0	0	58,024
1992	1/	2,453	185,627	1,533	0	0	189,613
1993	42,161	11,334	46,925	3,360	0	0	61,619
1994	80,470	2,454	118,710	4,575	0	0	125,739
1995	45,137	5,206	32,900	5,571	0	0	43,677
1996	182,460	3,268	296,295	6,369	0	0	305,932
1997	55,882 2/	27,826	71,930	2,137	0	0	101,893
1998	103,194	5,731	51,284		0		57,015
1999	33,991	3,422					3,422
2000	200,938						0
2001	72,388						
2002	48,054						

1/ Coho escapement was not counted in 1992. Runs of age-1.1 and age-3.1 coho for 1992 were estimated from relationship of spawners to returns and sibling to returns.
2/ Base on offshore test netting sonar estimates of coho passage significantly too low. Estimate of total coho escapement not available. Based on sonar counts, test net results, and observations escapement was greater than 50,000 coho salmon.
3/ Sonar counts were expanded in years that the sonar was terminated early.

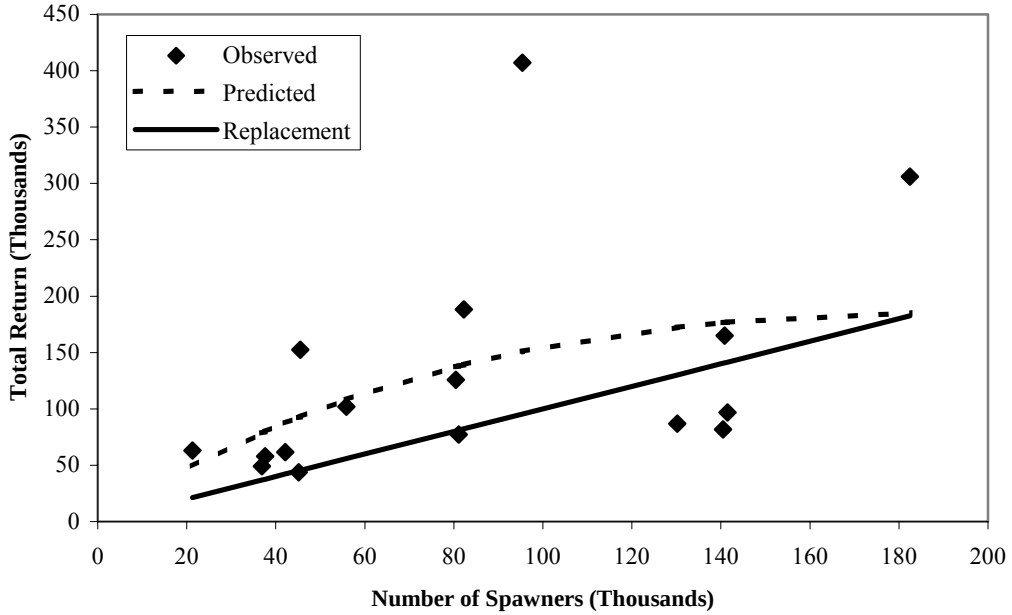
Appendix D2. – Continued.

System: **Nushagak River**
Species: **coho salmon**

ACF and PACF plots for Ricker stock-recruitment residuals, 1980-1997 brood years.



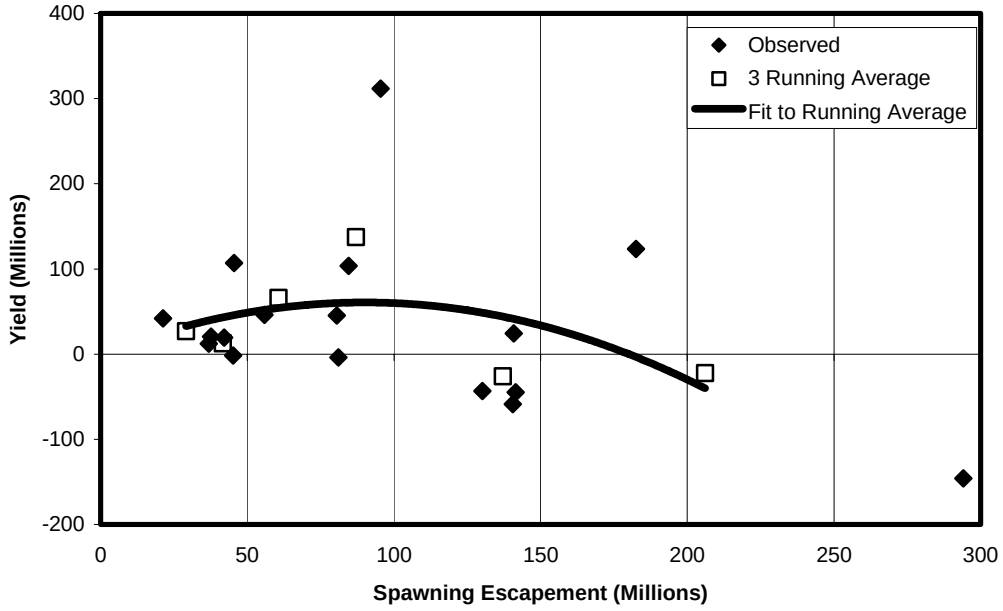
Ricker stock-recruitment relationship, 1980-1997 brood years.



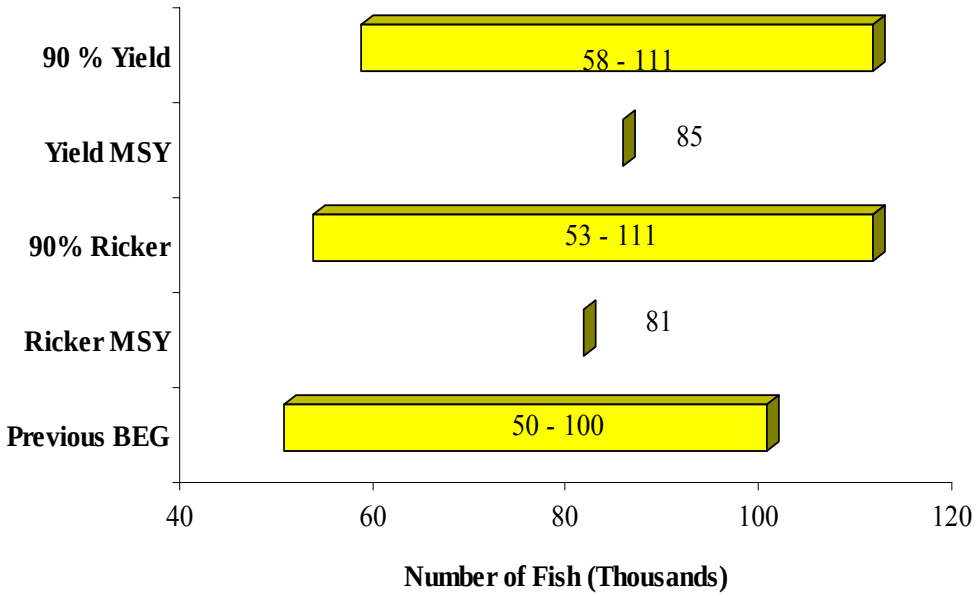
Appendix D2. – Continued.

System: **Nushagak River**
Species: **coho salmon**

Stock-yield relationship, 1980-1997 brood years.



Summary of current escapement goal and estimates of S_{MSY}.



Appendix D3. – Escapement goal for Kulukak River coho salmon.

System: Kulukak River
Species: coho salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	15,000 (1986)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	Dropped
Escapement Goal Type:	None
Escapement Estimation:	Expanded aerial survey counts since 1980
Summary:	
Data Quality	Poor
Data Type	Aerial survey; return estimates not available
Methodology	None
Autocorrelation	No significant autocorrelation
Years within recommended goal	Not applicable
Comments	The previous goal was based on late-season single aerial surveys that are often hampered by surveys. Because management decisions have not been made for this stock and due to budget reductions, it is highly unlikely that escapement surveys will be flown in the future. Therefore, no analyses were performed on these data.

Appendix D3. – Continued.

System: **Kulukak River**
Species: **coho salmon**

Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)
1980	30,900	10.34
1981	11,370	9.34
1982	10,140	9.22
1983		
1984	32,250	10.38
1985	23,370	10.06
1986		
1987	2,730	7.91
1988	5,520	8.62
1989		
1990	15,585	9.65
1991	12,600	9.44
1992	37,920	10.54
1993		
1994		
1995	3,555	8.18
1996	30,870	10.34
1997	5,025	8.52
1998	10,950	9.30
1999	1,500	7.31
2000		
2001	2,205	7.70
2002		
Mean	14,781	9.18
St. dev.	12,310	1.04
Median	11,160	9.32

APPENDIX E.
SUPPORTING INFORMATION FOR PINK SALMON ESCAPEMENT GOALS OF BRISTOL BAY

Appendix E1. – Escapement goal for Nushagak River pink salmon.

System: Nushagak River
Species: pink salmon

Description of stock and escapement goals.

Management Division:	Commercial Fisheries
Previous Escapement Goal:	600,000 – 1,100,000 (1992)
Inriver Goal:	None
Optimal Escapement Goal:	None
Recommended Escapement Goal:	Dropped
Escapement Goal Type:	None
Escapement Estimation:	Expanded aerial survey in 1958; Nuyakuk tower counts from 1960-1979; sonar counts from 1980 to present; 23 years of complete return data available, even years only
Summary:	
Data Quality	Good
Data Type	Aerial survey, tower, and sonar escapement estimates; commercial harvest; age data
Methodology	Risk analysis
Autocorrelation	No significant autocorrelation
Years within recommended goal	Not applicable
Comments	The analysis was conducted using years for which complete return data were available. The goal was dropped because the Nushagak River sonar project terminates on July 20 due to budget reductions and the majority of the escapement occurs after this date. Based on the available data and given sufficient funding, the recommended goal would be 280,000 with no upper bound.

Appendix E1. – Continued.

System: Nushagak River
Species: pink salmon

Data available for analysis of escapement goals.

Year	Escapement	ln(Escapement)	Commercial Harvest
1958	4,000,000	15.20	1,100,000
1960	100,000	11.51	300,000
1962	500,014	13.12	880,424
1964	908,500	13.72	1,497,817
1966	1,442,424	14.18	2,337,066
1968	2,161,116	14.59	1,705,150
1970	152,580	11.94	417,834
1972	58,536	10.98	67,953
1974	532,316	13.18	413,613
1976	836,278	13.64	739,590
1978	9,161,784	16.03	4,348,336
1980	2,749,746	14.83	2,202,545
1982	1,611,226	14.29	1,339,272
1984	2,833,362	14.86	3,127,153
1986	72,189	11.19	267,117
1988	494,610	13.11	243,890
1990	801,430	13.59	54,127
1992			190,102
1994	191,772	12.16	7,337
1996	821,312	13.62	2,681
1998	132,402	11.79	6,808
2000	135,285	11.82	38,309
2002	317,661	12.67	234
Mean	1,364,297	13.27	925,537
St. dev.	2,044,279	1.39	1,155,746
Median	666,873	13.39	413,613

Appendix E1. – Continued.

System: **Nushagak River**
Species: **pink salmon**

Risk analysis summary showing the risk of an unwarranted concern and the estimated risk that a drop in various levels of mean escapement would not be detected.